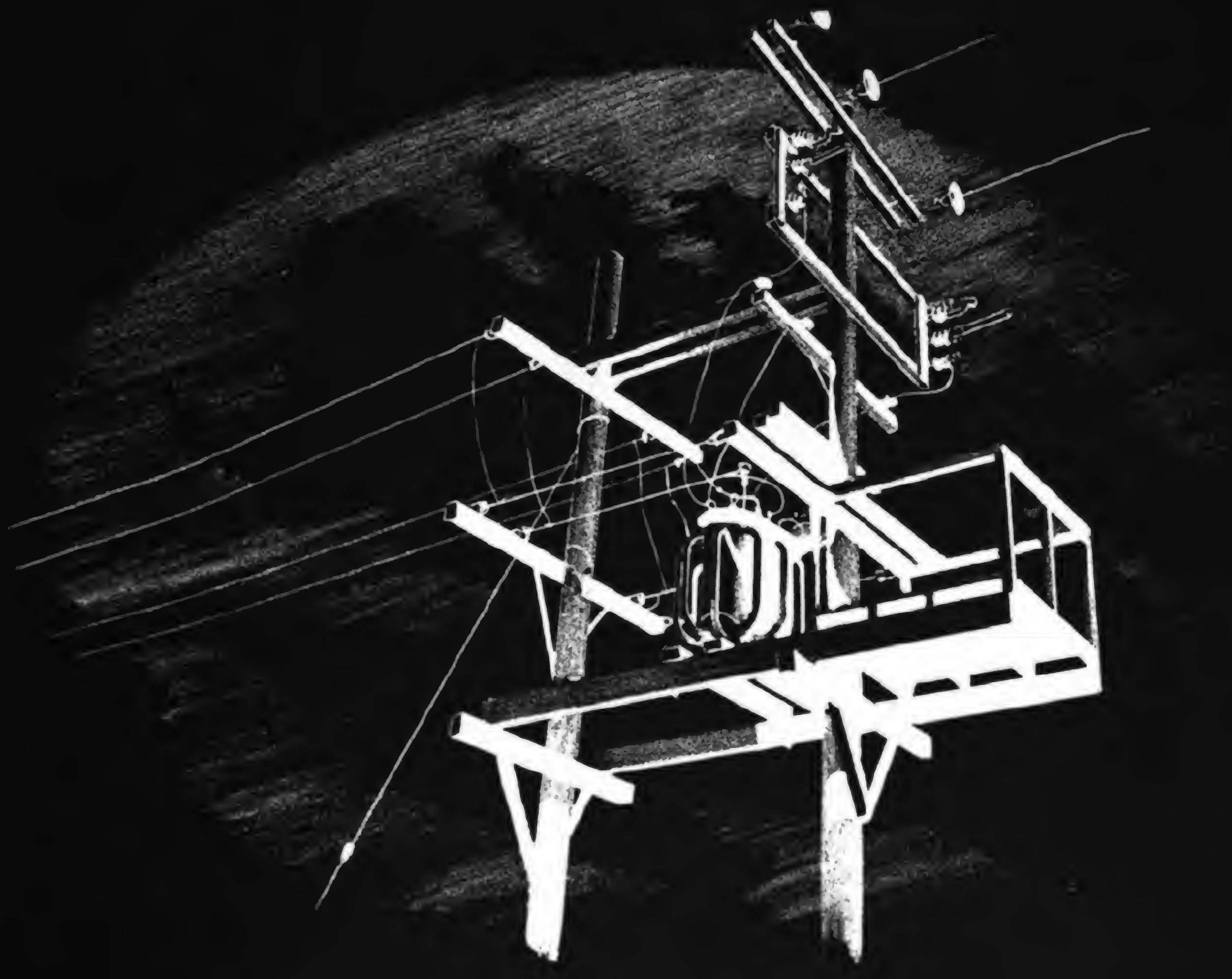

CONSTRUCTION ELECTRICIAN 1 & C

BUREAU OF NAVAL PERSONNEL

NAVY TRAINING COURSE NAVPERS 10637-B

PREFACE

This book has been written for men of the Navy and of the Naval Reserve who are studying for advancement to the rates of Construction Electrician First or Chief. Combined with the necessary practical experience, the information contained herein will aid the reader in preparing for an advancement in rating examination.

The first chapter of this book contains general information concerning the work and responsibilities of a Construction Electrician, First Class or Chief Construction Electrician together with suggestions for additional study aids. Subsequent chapters discuss electrical sketching and planning, controllers and protective devices, electrical testing equipment, power generators, power distribution equipment, wire communications, training, formanship, defensive combat, and ABC equipment.

As one of the Navy Training Courses, this book was prepared by the Navy Training Publications Center for the Bureau of Naval Personnel. Review for technical accuracy was contributed by the Construction Electricians' School, Port Hueneme, and by technical experts from the Bureau of Yards and Docks.

CREDITS FOR ILLUSTRATIONS

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THE UNITED STATES NAVY

GUARDIAN OF OUR COUNTRY

The United States Navy is responsible for maintaining control of the sea and is a ready force on watch at home and overseas, capable of strong action to preserve the peace or of instant offensive action to win in war.

It is upon the maintenance of this control that our country's glorious future depends; the United States Navy exists to make it so.

WE SERVE WITH HONOR

Tradition, valor, and victory are the Navy's heritage from the past. To these may be added dedication, discipline, and vigilance as the watchwords of the present and the future.

At home or on distant stations we serve with pride, confident in the respect of our country, our shipmates, and our families.

Our responsibilities sober us; our adversities strengthen us.

Service to God and Country is our special privilege. We serve with honor.

THE FUTURE OF THE NAVY

The Navy will always employ new weapons, new techniques, and greater power to protect and defend the United States on the sea, under the sea, and in the air.

Now and in the future, control of the sea gives the United States her greatest advantage for the maintenance of peace and for victory in war.

Mobility, surprise, dispersal, and offensive power are the keynotes of the new Navy. The roots of the Navy lie in a strong belief in the future, in continued dedication to our tasks, and in reflection on our heritage from the past.

Never have our opportunities and our responsibilities been greater.

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READING LIST

NAVY TRAINING COURSES

Construction Electrician 3 & 2, NavPers 10636-D

Basic Electricity, NavPers 10086-A

Electrician's Mate 1 & C NavPers 10547

USAFI TEXTS

United States Armed Forces Institute (USAFI) courses for additional reading and study are available through your Information and Education Officer.* A partial list of those courses applicable to your rate follows:

Number	Title
B 781	Fundamentals of Electricity
B 885	Fundamentals of Radio
B 890	Principles & Practices of Radio Servicing

* "Members of the United States Armed Forces Reserve Components, when on active duty, are eligible to enroll for USAFI courses, services, and materials, if the orders calling them to active duty specify a period of 120 days or more, or if they have been on active duty for a period of 120 days or more regardless of the time specified on the active duty orders."

CHAPTER 1
THE SCOPE OF YOUR JOB

Those stripes on your arm show that you have been a Construction Electrician long enough to realize the importance of your rating to the Navy. They indicate that you have learned your job well and mark you as having served the Navy as an expert in the field of electrical equipment—both power and communications.

From your years of experience, you undoubtedly realize the amount of care and efficient workmanship demanded of the men in your rating. In a construction battalion, especially, efficient operation is closely related to efficient installation and maintenance procedures for electrical equipment. As a CE1 or CEC, you will have an opportunity and a responsibility to see that the men whom you supervise are meeting required installation and maintenance standards.

Previously, in studying for advancement, you have concentrated upon increasing your technical skills and developing the knowledge essential to those who work on electrical equipment. Throughout your naval career, you must continue to study and to develop your knowledge and skills. As a CE1 or CEC, you have the additional responsibility of supervisory duties. A successful supervisor must be a leader, organizer, and teacher.

You are aware that you need actual experience to master a skill or a technique. You will find that you also need experience to become a good supervisor. But, just as you learned some of the fundamentals of electricity from textbooks, so you can learn of the principles of supervision from the experience of others. This text contains some of the technical aspects of your job and also some of the basic principles of good supervision.

The remainder of this chapter gives information that will help you in working for advancement in rating. It is strongly recommended that you study it carefully before beginning intensive study of the remainder of this training course.

THE ENLISTED RATING STRUCTURE

The present enlisted rating structure, established in 1957, includes three types of ratings: general ratings, service ratings, and emergency ratings.

GENERAL RATINGS are designed to provide paths of advancement and career development. A general rating identifies a broad occupational field of related duties and functions requiring similar aptitudes and qualifications. General ratings provide the primary means used to identify billet requirements and personnel qualifications. Some general ratings include service ratings; others do not. Both Regular Navy and Naval Reserve personnel may hold general ratings.

Subdivisions of certain general ratings are identified as SERVICE RATINGS. These service ratings identify areas of specialization within the scope of a general rating. Service ratings are established in those general ratings in which specialization is essential for efficient utilization of personnel. Although service ratings can exist at any petty officer level, they are most common at the PO3 and PO2 levels. Both Regular Navy and Naval Reserve personnel may hold service ratings.

EMERGENCY RATINGS identify essentially civilian occupations. Emergency ratings are not identified as ratings in the peacetime Navy, but their identification is required in time of war.

THE CONSTRUCTION ELECTRICIAN RATING

As a CE1 or CEC, you will be in a GENERAL RATING rather than in a SERVICE RATING. A general rating reflects qualifications in ALL aspects of an occupational field rather than in one aspect only. For example, a Construction Electrician in pay grade E4 or E5 is required to be proficient in only one phase of the CE rating—the wiring, power, telephone, or the shop phase. At the levels of E6 or E7, however, he is required to be competent in ALL phases

of the CE rating. You advanced through one of the CE service ratings—CEW, CEP, CET or CES. Before advancing to pay grade E6, it is necessary for you to learn the essentials of the other service ratings. If you have specialized, for example in power, you must learn about the other 3 service ratings as well. Before you advance to the rate of chief, you must learn how to CROSS TRAIN men in lower grades—that is, to give them training in the service ratings in which they have not specialized in order that they may advance to the general rating.

As a Navy fighting man you will also participate in the Navy leadership program set forth in General Order No. 21. The general order defines Navy leadership in the following terms:

By Naval leadership is meant the art of accomplishing the Navy's mission through people. It is the sum of those qualities of intellect, of human understanding and of moral character that enable a man to inspire and to manage a group of people successfully. Effective leadership, therefore, is based on personal example, good management practices, and moral responsibility. The term leadership as used in this order shall include all three of these elements.

Leadership and supervision are discussed in another section of this chapter.

ADVANCEMENT IN RATING

By this time, you are probably well aware of the personal advantages of advancement in rating—higher pay, greater prestige, more interesting and challenging work, and the satisfaction of getting ahead in your chosen career. By this time, also, you have probably discovered that one of the most enduring rewards of advancement is the training you acquire in the process of preparing for advancement.

The Navy also profits by your advancement. Highly trained personnel are essential to the functioning of the Navy. By each advancement in rating, you increase your value to the Navy in two ways. First, you become more valuable as a technical specialist in your own rating. And second, you become more valuable as a person who can supervise, lead, and train others and thus make far-reaching contributions to the entire Navy.

Since you are studying for advancement to PO1 or CPO, you are probably already familiar with the requirements and procedures for advancing in rating. However, you may find it helpful to read the following sections. The Navy does not stand still. Things change all the time, and it is possible that some of the requirements have changed since the last time you were going up for advancement in rating. Furthermore, you will be responsible for training others for advancement, and so will need to know the requirements in some detail.

HOW TO QUALIFY FOR ADVANCEMENT

To qualify for advancement in rating, a person must:

1. Have a certain amount of time in grade.
2. Complete the required military and professional training courses.
3. Demonstrate the ability to perform all the PRACTICAL requirements for advancement by completing applicable portions of the Record of Practical Factors, NavPers 760.
4. Be recommended by his commanding officer.
5. Demonstrate his KNOWLEDGE by passing a written examination on (a) military requirements, and (b) professional qualifications.

Some of these general requirements may be modified in certain ways. Figure 1-1 gives an overall view of the requirements for advancement of active duty personnel; figure 1-2 gives this information for inactive duty personnel.

Remember that the requirements for advancement can change. Check with your information and education officer to be sure that you know the most recent requirements.

When you are training lower rated personnel, it is a good idea to point out that advancement in rating is not automatic. Meeting all the requirements makes a person ELIGIBLE for advancement, but it does not guarantee his advancement. Such factors as the score made on the written examination, length of time in service, performance marks, and the quotas for the rating enter into the final determination of who will actually be advanced.

HOW TO PREPARE FOR ADVANCEMENT

Preparations for advancement in rating include studying the qualifications, working on the practical factors, studying the required Navy Training Courses, and studying any other

ACTIVE DUTY ADVANCEMENT REQUIREMENTS

<table>
<tr><th>REQUIREMENTS *</th><th>E1 to E2</th><th>E2 to E3</th><th>E3 to E4</th><th>E4 to E5</th><th>E5 to E6</th><th>E6 to E7</th><th>† E7 to E8</th><th>‡ E8 to E9</th></tr>
<tr><td>SERVICE</td><td>4 mos. service—or completion of recruit training.</td><td>6 mos. as E-2.</td><td>6 mos. as E-3.</td><td>12 mos. as E-4.</td><td>24 mos. as E-5.</td><td>36 mos. as E-6.</td><td rowspan="2">48 mos. as E-7. 8 of 11 years total service must be enlisted. Must be permanent appointment.</td><td rowspan="2">24 mos. as E-8. 10 of 13 years total service must be enlisted.</td></tr>
<tr><td>SCHOOL</td><td>Recruit Training.</td><td></td><td>Class A for PR3, DT3, PT3. ǂAME 3</td><td></td><td></td><td>Class B for AGCA, MUCA, MNCA.</td></tr>
<tr><td>PRACTICAL FACTORS</td><td>Locally prepared check-offs.</td><td colspan="7">Records of Practical Factors, NavPers 760, must be completed for E-3 and all PO advancements.</td></tr>
<tr><td>PERFORMANCE TEST</td><td colspan="2"></td><td colspan="4">Specified ratings must complete applicable performance tests before taking examinations.</td><td></td><td></td></tr>
<tr><td>ENLISTED PERFORMANCE EVALUATION</td><td colspan="2">As used by CO when approving advancement.</td><td colspan="6">Counts toward performance factor credit in advancement multiple.</td></tr>
<tr><td>EXAMINATIONS</td><td colspan="2">Locally prepared tests.</td><td colspan="4">Service-wide examinations required for all PO advancements.</td><td colspan="2">Service-wide, selection board, and physical.</td></tr>
<tr><td>NAVY TRAINING COURSE (INCLUDING MILITARY REQUIREMENTS)</td><td></td><td colspan="5">Required for E-3 and all PO advancements unless waived because of school completion, but need not be repeated if identical course has already been completed. See NavPers 10052 (current edition).</td><td colspan="2">Correspondence courses and recommended reading. See NavPers 10052 (current edition).</td></tr>
<tr><td rowspan="2">AUTHORIZATION</td><td colspan="2">Commanding Officer</td><td colspan="3">U.S. Naval Examining Center</td><td colspan="3">Bureau of Naval Personnel</td></tr>
<tr><td colspan="6">TARS are advanced to fill vacancies and must be approved by CNARESTRA.</td><td colspan="2"></td></tr>
</table>

* All advancements require commanding officer's recommendation.
† 2 years obligated service required.
‡ 3 years obligated service required.
ǂ Effective 1 Jan. 1963.

Figure 1-1.—Active duty advancement requirements.

INACTIVE DUTY ADVANCEMENT REQUIREMENTS

REQUIREMENTS *		E1 to E2	E2 to E3	E3 to E4	E4 to E5	E5 to E6	E6 to E7	E8	E9
	FOR THESE DRILLS PER YEAR								
TOTAL TIME IN GRADE	48 24 NON-DRILLING	6 mos. 9 mos. 12 mos.	6 mos. 9 mos. 24 mos.	15 mos. 15 mos. 24 mos.	18 mos. 18 mos. 36 mos.	24 mos. 24 mos. 48 mos.	36 mos. 36 mos. 48 mos.	48 mos. 48 mos.	24 mos. 24 mos.
DRILLS ATTENDED IN GRADE †	48 24	18 16	18 16	45 27	54 32	72 42	108 64	144 85	72 32
TOTAL TRAINING DUTY IN GRADE †	48 24 NON-DRILLING	14 days 14 days None	14 days 14 days None	14 days 14 days 14 days	14 days 14 days 14 days	28 days 28 days 28 days	42 days 42 days 28 days	56 days 56 days	28 days 28 days
PERFORMANCE TESTS				Specified ratings must complete applicable performance tests before taking examination.					
PRACTICAL FACTORS (INCLUDING MILITARY REQUIREMENTS)		Record of Practical Factors, NavPers 760, must be completed for all advancements.							
NAVY TRAINING COURSE (INCLUDING MILITARY REQUIREMENTS)		Completion of applicable course or courses must be entered in service record.							
EXAMINATION		Standard exams are used where available, otherwise locally prepared exams are used.						Standard EXAM, Selection Board, and Physical.	
AUTHORIZATION		District commandant or CNARESTRA					Bureau of Naval Personnel		

* Recommendation by commanding officer required for all advancements.
† Active duty periods may be substituted for drills and training duty.

Figure 1-2.—Inactive duty advancement requirements.

material that may be specified for the rate and rating. To prepare for advancement yourself or to help others prepare for advancement, you will need to be familiar with (1) the Quals Manual, (2) the Record of Practical Factors, NavPers 760, (3) a NavPers publication called Training Publications for Advancement in Rating, NavPers 10052, and (4) Navy Training Courses. The following sections describe these materials and give some information on how to use them to best advantage.

The Quals Manual

The Manual of Qualifications for Advancement in Rating, NavPers 18068 (with changes), gives the minimum requirements for advancement to each rate within each rating. This manual is usually called the "Quals Manual", and the qualifications themselves are often called "quals." The qualifications are of two general types: (1) military requirements, and (2) professional or technical qualifications. Military requirements apply to all ratings rather than to any one rating alone. Professional qualifications are technical or professional requirements that are directly related to the work of each rating.

Both the military requirements and the professional qualifications are divided into subject matter groups. Then, within each subject matter group, they are divided into PRACTICAL FACTORS and KNOWLEDGE FACTORS.

The professional qualifications for advancement in your rating are printed as an appendix at the back of this training course. These qualifications were current at the time this training course was printed. However, the Quals Manual is changed more frequently than Navy Training Courses are revised. By the time you are studying this training course, therefore, the quals for your rating may have been changed. Never trust any set of quals until you have checked the change number against an UP-TO-DATE copy of the Quals Manual.

In training others for advancement in rating, emphasize these three points about the quals:

1. The quals are the MINIMUM requirements for advancement to each rate within the rating. Personnel who study MORE than the required minimum will have a great advantage when they take the written examinations for advancement.

2. Each qual has a designated rate level—chief, first class, second class, or third class. You are responsible for meeting all quals specified for the rate level to which you are seeking advancement AND all quals specified for lower rate levels. To advance to chief, therefore, you must meet all requirements for advancement to all rates within the rating.

3. The written examinations for advancement in rating will contain questions relating to the practical factors AND to the knowledge factors of BOTH the military requirements and the professional qualifications.

Record of Practical Factors

A special form known as the RECORD OF PRACTICAL FACTORS, NavPers 760, is used to record the satisfactory performance of the practical factors. This form, which is available for all ratings, lists all the military and all the professional practical factors. Whenever a person demonstrates his ability to perform a practical factor, appropriate entries must be made in the DATE and INITIALS columns. As a PO1 or CPO, you will often be required to check the practical factor performance of lower rated personnel and to report the results to your supervising officer.

As changes are made periodically to the Quals Manual, new forms of NavPers 760 are provided when necessary. Extra space is allowed on the Record of Practical Factors for entering additional practical factors as they are published in changes to the Quals Manual. The Record of Practical Factors also provides space for recording demonstrated proficiency in skills which are within the general scope of the rating but which are not identified as minimum qualifications for advancement. Keep this in mind when you are training and supervising other personnel. If a person demonstrates proficiency in some skill which is not listed in the quals but which is within the general scope of the rating, report this fact to the supervising officer so that an appropriate entry can be made in the Record of Practical Factors.

When you are transferred, the Record of Practical Factors should be forwarded with your service record to your next duty station. It is a good idea to check and be sure that this form is actually inserted in your service record before you are transferred. If the form is not in your record, you may be required to start all over again and requalify in practical factors that have already been checked off. You should

also take some responsibility for helping lower rated personnel keep track of their practical factor records when they are transferred.

NavPers 10052

Training Publications for Advancement in Rating, NavPers 10052 (revised) is a very important publication for anyone preparing for advancement in rating. This publication lists required and recommended Navy Training Courses and other reference material to be used by personnel working for advancement in rating. NavPers 10052 is revised and issued once each year by the Bureau of Naval Personnel. Each revised edition is identified by a letter following the NavPers number. When using this publication, be SURE you have the most recent edition.

The required and recommended references are listed by rate level in NavPers 10052. It is important to remember that you are responsible for all references at lower rate levels, as well as those listed for the rate to which you are seeking advancement.

Navy Training Courses that are marked with an asterisk (*) in NavPers 10052 are MANDATORY at the indicated rate levels. A mandatory training course may be completed by (1) passing the appropriate Enlisted Correspondence Course that is based on the mandatory training course; (2) passing locally prepared tests based on the information given in the mandatory training course; or (3) in some cases, successfully completing an appropriate Navy school.

When training personnel for advancement in rating, do not overlook the section of NavPers 10052 which lists the required and recommended references relating to the military requirements for advancement. Personnel of all ratings must complete the mandatory military requirements training course for the appropriate rate level before they can be eligible to advance in rating. Also, make sure that personnel working for advancement study the references which are listed as recommended but not mandatory in NavPers 10052. It is important to remember that ALL references listed in NavPers 10052 may be used as source material for the written examinations, at the appropriate rate levels.

Navy Training Courses

There are two general types of Navy Training Courses. RATING COURSES (such as this one) are prepared for most enlisted ratings. A rating training course gives information that is directly related to the professional qualifications of ONE rating. SUBJECT MATTER COURSES or BASIC COURSES give information that applies to more than one rating.

Navy Training Courses are revised from time to time to bring them up to date. The revision of a Navy Training Course is identified by a letter following the NavPers number. You can tell whether a Navy Training Course is the latest edition by checking the NavPers number (and the letter following the number) in the most recent edition of List of Training Manuals and Correspondence Courses, NavPers 10061.

Navy Training Courses are designed for the special purpose of helping naval personnel prepare for advancement in rating. By this time, you have probably developed your own way of studying these courses. Some of the personnel you train, however, may need guidance in the use of Navy Training Courses. Although there is no single "best" way to study a training course, the following suggestions have proved useful for many people.

1. Study the military requirements and the professional qualifications for your rating before you study the training course, and refer to the quals frequently as you study. Remember, you are studying the training course primarily to meet these quals.

2. Before you begin to study any part of the training course intensively, get acquainted with the entire book. Read the preface and the table of contents. Check through the index. Thumb through the book without any particular plan, looking at the illustrations and reading bits here and there as you see things that interest you.

3. Look at the training course in more detail, to see how it is organized. Look at the table of contents again. Then, chapter by chapter, read the introduction, the headings, and the subheadings. This will give you a pretty clear picture of the scope and content of the book.

4. When you have a general idea of what is in the training course and how it is organized, fill in the details by intensive study. In each study period, try to cover a complete unit—it may be a chapter, a section of a chapter, or a subsection. The amount of material you can cover at one time will vary. If you know the subject well, or if the material is easy, you can cover quite a lot at one time. Difficult or unfamiliar material will require more study time.

5. In studying each unit, write down questions as they occur to you. Many people find it helpful to make a written outline of the unit as they study, or at least to write down the most important ideas.

6. As you study, relate the information in the training course to the knowledge you already have. When you read about a process, a skill, or a situation, ask yourself some questions. Does this information tie in with past experience? Or is this something new and different? How does this information relate to the qualifications for advancement in rating?

7. When you have finished studying a unit, take time out to see what you have learned. Look back over your notes and questions. Without looking at the training course, write down the main ideas you have gotten from studying this unit. Don't just quote the book. If you can't give these ideas in your own words, the chances are that you have not really mastered the information.

8. Use Enlisted Correspondence Courses whenever you can. The correspondence courses are based on Navy Training Courses or other appropriate texts. As mentioned before, completion of a mandatory Navy Training Course can be accomplished by passing an Enlisted Correspondence Course based on the training course. You will probably find it helpful to take other correspondence courses, as well as those based on mandatory training courses. Taking a correspondnece course helps you to master the information given in the training course, and also gives you an idea of how much you have learned.

INCREASED RESPONSIBILITIES

When you assumed the duties of a PO3, you began to accept a certain amount of responsibility for the work of others. With each advancement in rating, you accept an increasing responsibility in military matters and in matters relating to the professional work of your rating. When you advance to PO1 or CPO, you will find a noticeable increase in your responsibilities for leadership, supervision, training, working with others, and keeping up with new developments.

As your responsibilities increase, your ability to communicate clearly and effectively must also increase. The simplest and most direct means of communication is a common language. The basic requirement for effective communication is therefore a knowledge of your own language. Use correct language in speaking and in writing. Remember that the basic purpose of all communication is understanding. To lead, supervise, and train others, you must be able to speak and write in such a way that others can understand exactly what you mean.

Leadership and Supervision

As a PO1 or CPO, you will be regarded as a leader and supervisor. Both officers and enlisted personnel will expect you to translate the general orders given by officers into detailed, practical, on-the-job language that can be understood and followed by relatively inexperienced personnel. In dealing with your juniors, it is up to you to see that they perform their jobs correctly. At the same time, you must be able to explain to officers any important problems or needs of enlisted personnel. In all military and professional matters, your responsibilities will extend both upward and downward.

Along with your increased responsibilities, you will also have increased authority. Officers and petty officers have POSITIONAL authority—that is, their authority over others lies in their positions. If your CO is relieved, for example, he no longer has the degree of authority over you that he had while he was your CO, although he still retains the military authority that all seniors have over subordinates. As a PO1, you will have some degree of positional authority; as a CPO, you will have even more. When exercising your authority, remember that it is positional—it is the rate you have, rather than the person you are, that gives you this authority.

Training

As a PO1 or CPO, you will have regular and continuing responsibilities for training others. Even if you are lucky enough to have a group of subordinates who are all highly skilled and well trained, you will still find that training is necessary. For example, you will always be responsible for training lower rated personnel for advancement in rating. Also, some of your best workers may be transferred; and inexperienced or poorly trained personnel may be assigned to you. Or a particular job may call for skills that none of your personnel have. These and similar problems require that you be a

training specialist—one who can conduct formal and informal training programs to qualify personnel for advancement in rating, and one who can train individuals and groups in the effective execution of assigned tasks.

In using this training course, study the information from two points of view. First, what do you yourself need to learn from it? And second, how would you go about teaching this information to others?

Training goes on all the time. Every time a person does a particular piece of work, some learning is taking place. As a supervisor and as a training expert, one of your biggest jobs is to see that your personnel learn the RIGHT things about each job so that they will not form bad work habits. An error that is repeated a few times is well on its way to becoming a bad habit. You will have to learn the difference between oversupervising and not supervising enough. No one can do his best work with a supervisor constantly supervising. On the other hand, you cannot turn an entire job over to an inexperienced person and expect him to do it correctly without any help or supervision.

In training lower rated personnel, emphasize the importance of learning and using correct terminology. A command of the technical language of your rating enables you to receive and convey information accurately and to exchange ideas with others. A person who does not understand the precise meaning of terms used in connection with the work of his rating is definitely at a disadvantage when he tries to read official publications relating to his work. He is also at a great disadvantage when he takes the examinations for advancement in rating. To train others in the correct use of technical terms, you will need to be very careful in your own use of words. Use correct terminology and insist that personnel you are supervising use it too.

You will find the Record of Practical Factors, NavPers 760, a useful guide in planning and carrying out training programs. From this record, you can tell which practical factors have been checked off and which ones have not yet been done. Use this information to plan a training program that will fit the needs of the personnel you are training.

On-the-job training is usually controlled through daily and weekly work assignments. When you are working on a tight schedule, you will generally want to assign each person to the part of the job that you know he can do best. In the long run, however, you will gain more by assigning personnel to a variety of jobs so that each person can acquire broad experience. By giving people a chance to do carefully supervised work in areas in which they are relatively inexperienced, you will increase the range of skills of each person and thus improve the flexibility of your working group.

Working With Others

As you advance to PO1 or CPO, you will find that many of your plans and decisions affect a large number of people, some of whom are not even in your own rating. It becomes increasily important, therefore, for you to understand the duties and the responsibilities of personnel in other ratings. Every petty officer in the Navy is a technical specialist in his own field. Learn as much as you can about the work of other ratings, and plan your own work so that it will fit into the overall mission of the organization.

Keeping Up With New Developments

Practically everything in the Navy—policies, procedures, publication, equipment, systems—is subject to change and development. As a PO1 or CPO, you must keep yourself informed about changes and new developments that affect you or your work in any way.

Some changes will be called directly to your attention, but others you will have to look for. Try to develop a special kind of alertness for new information. When you hear about anything new in the Navy, find out whether there is any way in which it might affect the work of your rating. If so, find out more about it.

SOURCES OF INFORMATION

As a PO1 or CPO, you must have an extensive knowledge of the references to consult for accurate, authoritative, up-to-date information on all subjects related to the military requirements for advancement and the professional qualifications of your rating.

Some of the publications mentioned here are subject to change or revision from time to time—some at regular intervals, others as the need arises. When using any publication that is subject to change or revision, make sure that

you have the latest edition. When using any publication that is kept current by means of changes, be sure you have a copy in which all official changes have been made.

NAVY TRAINING COURSE FORCE

As mentioned earlier, a CE1 or CEC is responsible for all of the qualifications required for a lower rated CE, as well as for his own rate. It may therefore be helpful to review material in the Construction Electrician 3 & 2 training course as well as studying this course. You might also get helpful information from the Electrician Mate training courses, and other professional or basic courses.

A number of training courses are prepared specifically to cover military requirements. These courses include Basic Military Requirements, NavPers 10054; Military Requirements for Petty Officer 3 & 2, NavPers 10056, and Military Requirements for Petty Officer 1 & C, NavPers 10057. Although you have probably studied these courses before, you may find that a review will be helpful. NavPers 10057, in particular, is geared for personnel studying for pay grades E6 and E7. The course contains much useful material on teaching methods and supervision.

The Manual for Navy Instructors, NavPers 16103-B, is a special purpose publication that is especially useful for personnel who have to carry on formal instruction programs. It discusses methods of instruction, lesson plans, testing, instruction sheets, and similar matters of interest to instructors. You will find this a helpful publication if you give your men formal or informal training.

OTHER GOVERNMENT PUBLICATIONS

Many of the reference materials helpful for the CE rating are issued by the United States Government. Your training officer should be able to obtain these materials for use at your activity. If you desire a personal copy of a Government publication, write to the Superintendent of Documents, Government Printing Office, Washington 25, D.C. and inquire whether the publication you desire is for sale; many, in fact, are available through this source.

BuDocks Publications

The Bureau of Yards and Docks issues a number of publications that are of benefit to Construction Electricians. Electrical Power Generation, chapter 1, TP-Pu-3; Mobile Emergency Power Plants, chapter 2, TP-Pu-3; Electric Power Distribution, chapter 8, TP-Pu-3; Advance Base Electrical and Communication Systems, TP-PL-15; and Wire Communications and Signal Systems, chapter 1, TP-Pe-5, for example, contain a great deal of information on power generators, power distribution, emergency power plant and communications systems. Although these publications are intended for practical use in the field, they also make useful reference books for self-study or instruction.

Mobile Construction Battalion Administration, NavDocks P-315, is a guide for the organization and administration of MCBs. This publication describes battalion organization operations, training, safety, and similar matters. NavDocks P-315 is a useful publication for MCB officers and petty officers.

The Navy Civil Engineer, NavDocks P-330, is a monthly magazine issued by BuDocks. This magazine is sent to all Civil Engineer Corps officers, so there should be several copies in your battalion. The Navy Civil Engineer is intended to keep CEC officers and other interested personnel abreast of developments in the Shore Establishment with respect to planning, design, construction, and maintenance. Most articles discuss Seabee operations or technical developments.

Army Technical Manuals

The Army has issued a series of technical manuals (TMs) on many topics of interest to Construction Electricians. The TM 5- series contains information on electrical power equipment, distribution, maintenance, and installation. The TM 9- series contains information on electrical communications equipment. You will find many of the publications in the 5 and 9 series very helpful.

The titles of all TMs are listed in the Index of Technical Manuals, Department of the Army Pamphlet No. 310-4.

Landing Party Manual

The Landing Party Manual, OPNAV P 34-03, is the Navy's guide for organizing landing

parties from units afloat and emergency ground defense force units. It contains chapters on such matters as military drill ceremonies, interior guard duty, special operations, combat techniques, and combat principles among others. The chapters on combat are particularly important to men in the Seabee ratings, since Seabees are responsible for defending their own areas.

MANUFACTURERS' MANUALS

When new equipment is procured by the Navy, this equipment almost always is accompanied by a manual of operating, maintenance, and installation instructions. These manuals should be kept readily available for reference. They describe in detail the procedures for installing, operating and maintaining a specific piece of equipment.

Study the manuals for each piece of equipment for which you are responsible; make certain that you understand the manual thoroughly. It will be the men assigned to you, of course—not you—who will actually install and maintain the equipment. Your responsibility is to make certain that the men understand their equipment and that they know how to follow the instructions in the manufacturer's manual or manuals for a specific piece of equipment. To carry out your responsibility in this respect, you must become thoroughly familiar with both the equipment and the accompanying manuals.

COMMERCIAL PUBLICATIONS

There are many commercial publications of use to Construction Electricians. Numerous texts have been published dealing with the fundamentals of electricity to the complex engineering phases. You will profit by studying some of these texts to increase your knowledge; you may also find some of these texts helpful as instruction manuals for your men.

No attempt will be made here to list all commercial publications that may be useful; only two will be mentioned. The officers in your battalion may be able to recommend others; some commercial texts may be available in your battalion.

The Lineman's Handbook by Edwin B. Kurtz, published by McGraw-Hill Book Company Inc. of New York, New York, is a handbook covering all phases of power distribution, construction and maintenance procedures. It may be used as a home-study book for those in the CEP rating.

National Electrical Code, by National Board of Fire Underwriters, New York, New York, is an excellent guide for proper and safe procedures in installing electrical devices.

TRAINING FILMS

Training films available to naval personnel are a valuable source of supplementary information on many technical subjects. A selected list of training films that may be useful to you is given in Appendix I of this training course. Other films that may be of interest are listed in the United States Navy Film Catalog, NavPers 10000 (revised).

ADVANCEMENT OPPORTUNITIES FOR PETTY OFFICERS

Making chief is not the end of the line as far as advancement is concerned. Proficiency pay, advancement to E-8 and E-9, and advancement to commissioned officer status are among the opportunities that are available to qualified petty officers. These special paths of advancement are open to personnel who have demonstrated outstanding professional ability, the highest order of leadership and military responsibility, and unquestionable moral integrity.

PROFICIENCY PAY

The Career Compensation Act of 1949, as amended, provides for the award of proficiency pay to designated enlisted personnel who possess special proficiency in a military skill. Proficiency pay is given in addition to your regular pay and allowances and any special or incentive pay to which you are entitled. Enlisted personnel in pay grades E-4 through E-9 are eligible for proficiency pay. Proficiency pay is allocated by ratings, with most awards being given in the ratings which are designated as critical. The eligibility requirements for proficiency pay are subject to change. In general, however, you must be recommended by your commanding officer, have a certain length of time on continuous active duty, and get a sufficiently high mark on a Navy-wide proficiency examination in the subject matter of your own rating.

ADVANCEMENT TO E-8 AND E-9

Chief petty officers may qualify for the advanced grades E-8 and E-9 which are now provided in the enlisted pay structure. These advanced grades provide for substantial increases in pay, together with increased responsibilities and additional prestige. The requirements for advancement to E-8 and E-9 are subject to change, but in general include a certain length of time in grade, a certain length of time in the naval service, a recommendation by the commanding officer, and a sufficiently high mark on the servicewide examination. The final selection for E-8 and E-9 is made by a regularly convened selection board.

ADVANCEMENT TO COMMISSIONED OFFICER

The Limited Duty Officer (Temporary) Program provides a path of advancement to commissioned officer status for outstanding petty officers of the Regular Navy. LDOs are limited, in their duty, to the broad technical fields associated with their former rating.

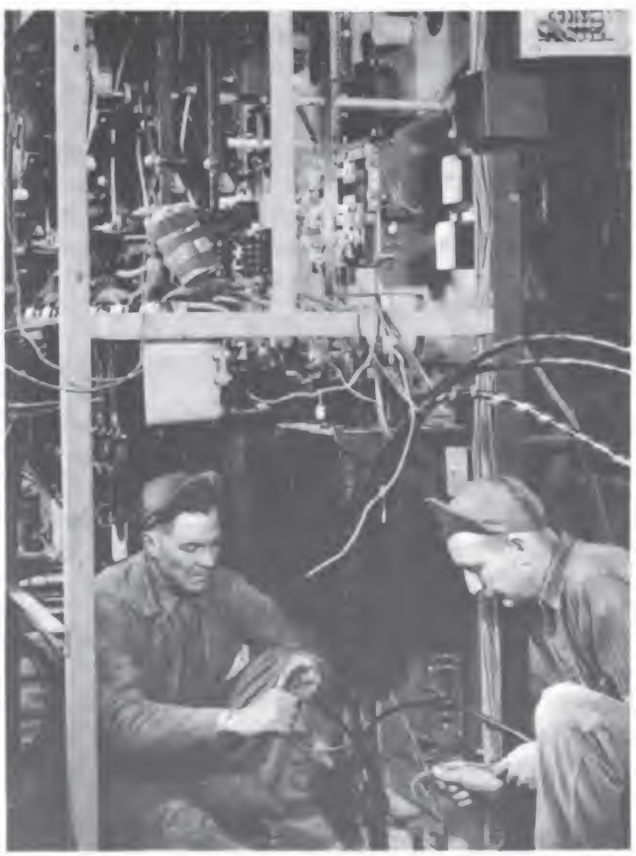
Advancement to LDO may be made from PO1 or above. Education, length of service, and maximum age limits are usually specified in the requirements for advancement to LDO. However, these requirements vary according to circumstances. If you are interested in advancing to LDO, ask your information and education officer for the latest requirements that apply to your particular case.

Another path of advancement to commissioned officer status is provided by the Integration Program. Enlisted personnel possessing the required qualifications may be appointed under this program to the grade of ensign in the Line, Supply, or Civil Engineer Corps of the Regular Navy. Education, length of service, and maximum age limits are included in the requirements for eligibility under this program. Eligibility requirements for this program, as well as for the other programs discussed here, are subject to change.

CHAPTER 2
ELECTRICAL SKETCHING AND PLANNING

Blueprints, schematics, wiring diagrams, drawings, and plans are familiar to you by now. But did you ever stop to realize the important part they play in your work as a Construction Electrician? Wiring a building, installing equipment, and locating troubles are all simplified through the use of electrical drawings.

Take a look at figure 2-1. How long do you think it would take to wire that switchboard if an electrician has to stop and figure out each connection separately? Probably about 6 months. But with the aid of a drawing it could be finished in a few days.



26.1
Figure 2-1.—Wiring a switchboard.

Most first-and second-class CEs have had some experience working with drawings. But, if you haven't had the opportunity to work with the many types of drawings, this chapter will give you a glimpse of the application and importance of each drawing in electrical construction, and how to sketch and lay out a drawing using the proper symbols.

There are two Navy Training Courses listed in TRAINING PUBLICATIONS for ADVANCEMENT in RATING, NavPers 10052 that you should be familiar with; Construction Electrician 3 & 2, NavPers 10636-D, and Blueprint Reading and Sketching, NavPers 10077-A. If you have properly studied chapters 1, 6 and 9 of the latter and chapter 3 of the former, you should be familiar with the basic sketching techniques. You should also be familiar with the various types of drawings such as orthographic, isometric, perspective, and so on; and parts of drawings, such as symbols, title block, bill of material, notes, legends, details, and cross sections.

MAKING SENSE OUT OF SYMBOLS

The major difficulty you may have experienced in trying to read prints may be summed up in one fact--your unfamiliarity with the symbols and abbreviations used. This is understandable, however, for there are several thousand symbols. To make the situation worse, draftsmen have not always used the same symbols or abbreviations to represent certain items. Fortunately, however, the armed services have standardized the use of these symbols and abbreviations. To eliminate discrepancies, a Military Standard for Electrical and Electronic Symbols, MIL-STD-15A, Abbreviations for Use on Drawings, MIL-STD-12A, Electrical and Electronics Reference Designations, MIL-STD-16B and Abbreviations (for Electrical and Electronics Use) MIL-STD-103, have been issued. These publications list the proper electrical symbols and abbreviations to be used on all military drawings.

Always try to picture the item a symbol is representing. Then, as you trace each circuit, you will begin to visualize the proper location of the various pieces and their importance to the complete installation. Figure 2-2 illustrates each item opposite its corresponding symbol.

The best way to learn how to recognize symbols and abbreviations is through practice. Avail yourself of every opportunity to study the prints of the installation to which you are assigned. Trace the circuits and find out the meaning of each unfamiliar symbol and abbreviation that you encounter. Then go back, when the installation is completed, and compare the finished job with the prints. All the lines, abbreviations, notes, and symbols will fit into a definite pattern.

SKETCHING

Sketching is a freehand method of drawing shape, size, and/or location of objects, and is a convenient and important means of communication. Objects or views can normally be drawn more quickly freehand than with instruments.

The First Class and Chief CE should develop a habit of furnishing sketches with appropriate electrical symbols, to members of his crew that are assigned projects (other than routine jobs). Equipped with a sketch or plan of the work to be done, the men will normally be better informed on what is to be done, will be able to determine the exact amount and type of material required, and will make less errors. This will result in a saving of time and material.

MODIFICATION OF BUILDINGS

BuDocks has prepared a series of drawings (NavDock P-140) to cover most installations used at advance bases. There are occasions, however, when a building is required to be modified or used for another purpose than originally intended.

Let us assume that, with more emphasis being placed on atomic, biological, and chemical warfare, there is a need to train personnel in disaster control. Figure 2-3 shows a floor plan of a typical advance base storage building, modified by adding an ABC gear storage room, equipment maintenance room, and the layout of the required classroom furniture. Let's further assume that you are to sketch a wiring diagram for the above mentioned floor plan and to provide some general information on the light and power requirements. How would you sketch it?

In general your sketch would probably be similar to the one illustrated in figure 2-3. This particular sketch will serve three important purposes:

1. It will graphically show the originator (P & E officer) the exact location of the lights and power outlets, and give him an opportunity to make changes if necessary, before final approval.
2. It will serve as a blueprint for CEs to follow in the actual wiring of the building.
3. It can be utilized to estimate the amount and type of material required to complete the project.

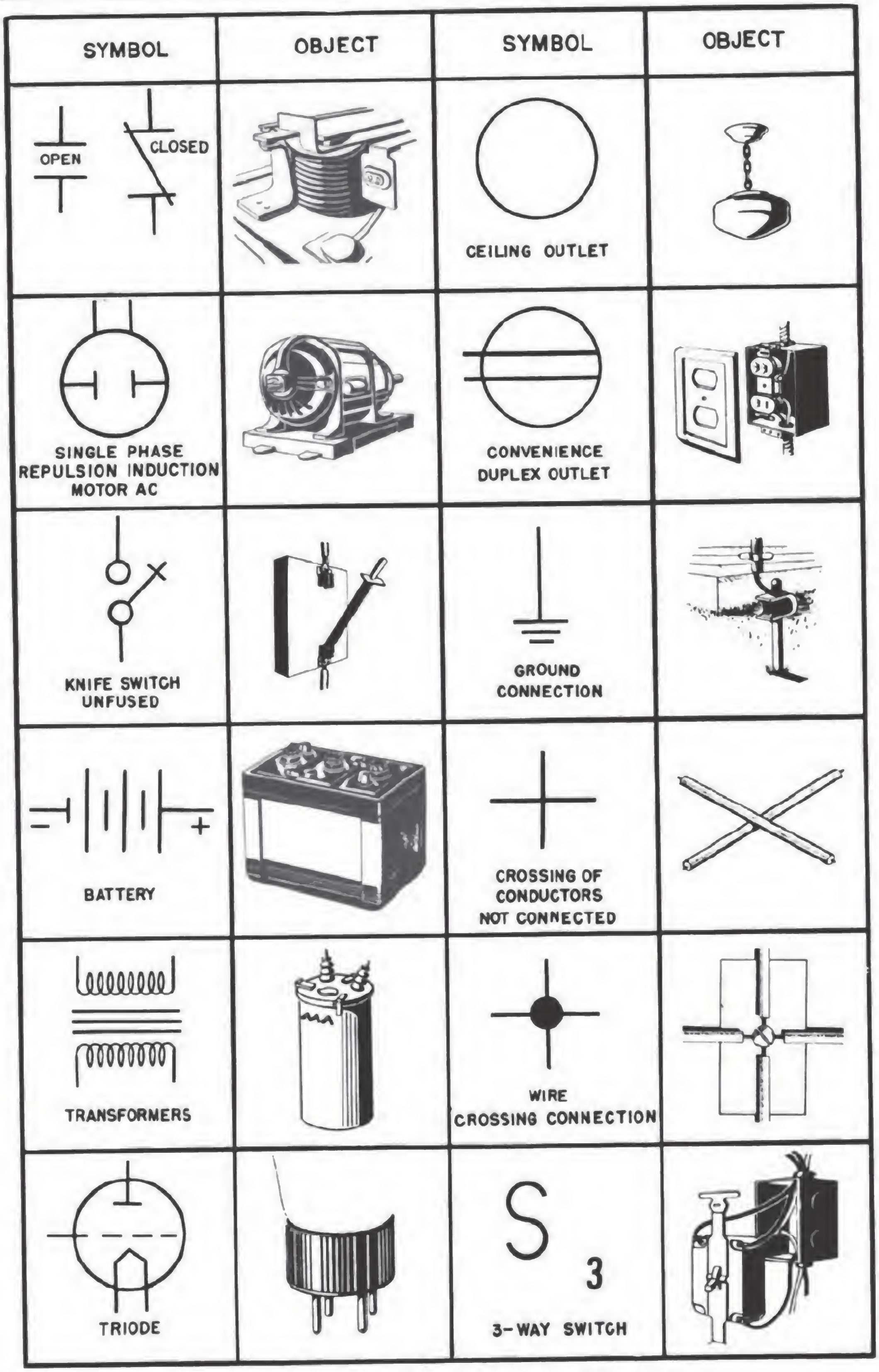
A simple sketch can be a tremendous help, particularly to third class CEs who have had little or no experience in some phases of wiring.

Let's take a hypothetical case of a power failure caused by a damaged transformer connected delta-delta, three-phase, in a three-transformer bank. The center transformer of the bank is defective. The transformer cannot be readily repaired, and a replacement will not be available for a couple of days. Your immediate decision is to connect the two remaining transformers in an open delta connection and in this way supply approximately 60 percent of the load. You have a third class CE available who has had very little experience in transformer connection, and you feel that he does not understand just how to make an open delta connection. If you draw a rough sketch such as the one illustrated in figure 2-4, showing the third class how to connect the two remaining transformers, open delta, it will be almost impossible for him to err.

A sketch such as the one illustrated in figure 2-4 will help to instill confidence in some of the less experienced personnel in your crew, and give them a better understanding, in this case, of a three-phase, two transformer, open-delta connection.

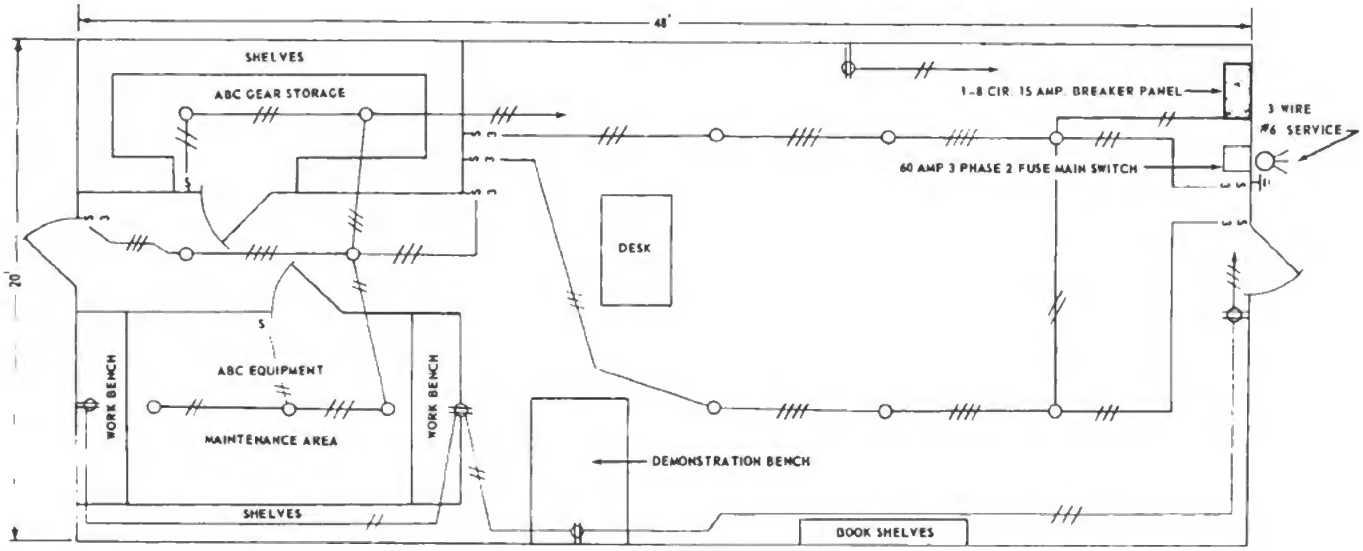
ADDITION TO EXISTING FACILITIES

A knowledge of sketching will come in handy when you are required to assign your crew to a job rearranging existing lighting, or to supply additional lighting to increase the foot candlepower. It will also help when you need to add special wiring for additional apparatus or equipment; add switches and outlets due to adding partitions, entrances and exits; and increase power load due to additional electrical consumption over and beyond estimated need.



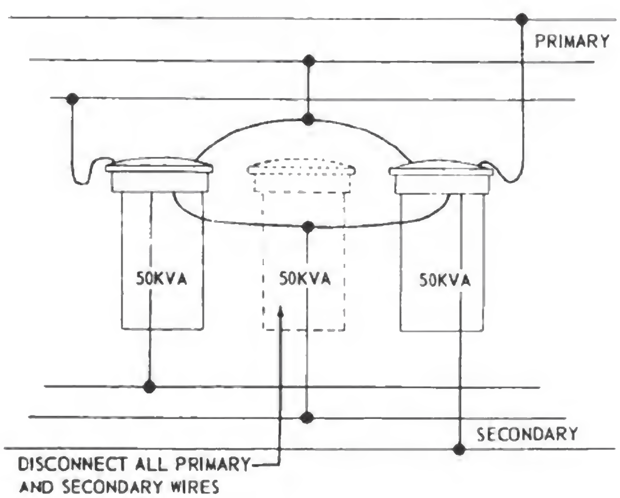
26.2

Figure 2-2.—Interpreting electrical symbols.



26.3

Figure 2-3.—An electrical sketch.



26.4

Figure 2-4.—A sketch of two transformers connected open delta.

Switches and Outlets

Normally switches are located near entrances and exits. Your main concern will be whether they are to be a one-way (S), three-way (S_3), or four-way (S_4) switch. Convenient outlets, however, require a little more foresight and planning to properly place them. Observe some of the buildings now being used as offices, note the extension cords required for the desk lights, electrical typewriters, and other electrical equipment. Good planning would eliminate 90 to 100 percent of the extension cords. If you are required to install electrical outlets in a building, give careful consideration to locating a few extra outlets for future expansion or rearrangement of the furniture.

Electrical Apparatus and Equipment

With technological advancements, larger and better equipment frequently requiring more power are constantly replacing older and outdated electrical equipment. Sometimes this requires more than adding an extension or another convenience outlet. It may however, involve an increase in voltage and amperage.

Increasing the Power Load

Modifying or making additions to existing facilities may increase the load to a greater value than the safe carrying capacity of present wiring or apparatus. Usually this will be indicated by frequent blowing of fuses and abnormally hot wiring or equipment. When an overload appears to exist, the actual current should be measured with an ammeter. Wattage of all lamps, devices, and other equipment connected to the overloaded circuit should also be checked.

An apparently overloaded circuit may sometimes be only a partially grounded circuit. If an overload is discovered, part of the load should be transferred to another circuit or the wiring should be replaced to provide adequate current capacity.

There may be instances when several buildings in a specific area require such an increase in load demand that the distribution transformer serving that area becomes inadequate; thereby requiring it to be replaced with a larger one.

TECHNICAL REQUIREMENTS

There are certain basic technical knowledges of design that you should be familiar with before you can sketch and design wiring plans to meet specified Navy requirements.

Most of the technical guidance for design and planning of waterfront facilities, building wiring (interior wiring), street lighting (exterior lighting), and other types of electrical guidance is the responsibility of BuDocks. Some of these design criteria will be discussed in this chapter.

WATERFRONT FACILITIES

The design of power systems for waterfront facilities is based on standard criteria and practices similar to those for other locations. Modifications may be necessary, however, to enable them to withstand the moist, usually salt-laden air, or to make them suitable in locations that are alternately wet and dry. Corrosion prevention and safe wiring practices are also important considerations.

Duct Lines

When you are required to use conduit for protecting wire around waterfront facilities, you should use fiber or asbestos cement duct. Rigid-steel conduit should be used ONLY to meet particular design problems. When necessary to install conduits where they will be exposed to wave action, as underneath piers or similar structures, asbestos-cement conduit, supported with steel hangers at not more than 5 foot intervals, is recommended.

Pier Outlets

Pier outlets for ship-service or portable equipment should be the protected type and should supply 440 volt, 3-phase power. The outlet is basically a 3-pole, 3-wire receptacle, with circuit-breaker protection, housed in a watertight enclosure of heavy welded-steel plate.

The nominal rating of the outlet is 200 or 400 amperes. For capacities between 400 and 1600 amperes, 400-ampere outlets should be provided in a number sufficient to total the required number of amperes. When a single outlet is designed for capacities of more than 1600 amperes, it should have bus bars and provisions for bolting on cable connections, and should be housed in a suitable enclosure.

The design of the installation should assure coordination between the interrupting ratings of the circuit breakers in the feeders and the circuit breakers at the outlets. A single outlet for more than 1600 amperes should have a circuit breaker at the outlet, if practicable, or in the feeder at the point of distribution.

Grounding

At waterfront facilities, a ground system that shall measure not more than 10 ohms should be provided for all permanent electrical equipment. The ground system should be in accordance with the acceptable Navy electrical code. The water-piping system on a structure is recommended as a ground for electrical equipment enclosures on the structure. Stranded-copper-wire ground conductors should be used to interconnect all electrical equipment enclosures and the water-pipe ground. The sizes of the ground conductors from enclosures, cable sheaths, steel conduits, transformer cases, or other devices are determined by the American Wire Gauge (AWG) size of conductors enclosed, as shown in table 2-1.

Table 2-1.—American Wire Gauge Conductor Sizes.

Size (AWG) of largest conductor or equivalent for multiple conductors	Ground Conductor AWG No.
2 or smaller	8
1 or 0	6
00 or 000	4
Over 000 to 350,000 CM*	2
Over 350,000 CM to 600,000 CM	0
Over 600,000 CM to 1,100,000 CM	00
Over 1,100,000 CM	000

* Circular mils.

The ground conductor on the structure should be protected at all places where it may be damaged. It is preferable to install the ground conductor in conduit or in the duct system in order to provide mechanical protection, but the ground conductor may be installed in the open if the installation is such that the conductor is thoroughly protected. When lead-covered cables are installed in ducts which may be partially immersed in water, or when water resulting from condensation or other causes remains in the ducts for long periods, the ground conductor in the duct line should be insulated with not less than 1/32 of an inch of a polyvinyl chloride type of insulation. This insulation reduces the possibility of corrosion of the lead sheath.

Structures that are not adjacent to a water-piping system should have a ground conductor system extended from the grounded devices to a driven ground rod system. The ground conductor in this case should be No. 6 AWG minimum and need be no larger except where a larger size will provide additional mechanical strength under certain conditions. Where it is not practical to properly maintain an onshore ground rod system adjacent to the pier, metal plates lowered to the bottom of the water should be used. The conductor connecting these plates to the No. 6 AWG conductor on the structure should be at least No. 2 AWG stranded copper wire in order to provide sufficient mechanical strength.

Cable and wire used in waterfront facilities should be a type suitable for installation in wet locations. Type RHL, heat-resistance rubber with lead covered cable, should be used for cables in sizes up to and including No. 2 AWG, and type VCL, varnish cambric lead covered cable, for sizes larger than No. 2 AWG. Wiped joints should be employed in making splices. At terminations an approved type of compound-filled terminal device should be used.

EXTERIOR LIGHTING

When exterior lighting is required for streets, roadways and piers at naval activities, careful consideration should be given to the type and design of the system and to the mounting luminaires so as to obtain a uniform level of illumination of sufficient intensity without glare.

The tendency, in the case of street lighting at naval activities, is toward higher levels of illumination and the use of the pendant type of luminaire in place of the post type with general diffusing fixtures.

Modern practice is to install the luminaires over the street for better distribution of light. If you are assigned the project of planning and lighting at any naval activity, you should exercise care in specifying the mounting of luminaires so that interference with moving cranes and large pieces of equipment will be avoided. This is particularly applicable to areas near waterfronts, railroad tracks, and piers used for general repair and fitting-out and supply.

Street Lighting Intensities

Lighting intensities should conform to those given in table 2-2 for pedestrian and vehicular traffic. In general, waterfront streets, main streets with railroad tracks in the industrial sections of large yards and general repair facilities, and fitting-out and supply piers should be classified for medium pedestrian and medium vehicular traffic. For cross streets in the industrial sections of large yards, residential streets, main streets in secondary naval activities, hospitals, and the like, the classifications should be light pedestrian and light vehicular traffic. Foot-candle intensity calculations are generally made by the average flux method or the point-by-point method. In employing the horizontal and vertical candlepower distribution, curves are used. These curves together with applicable data are available from manufacturers of street lighting equipment.

Table 2-2.—Street-Lighting Intensities.

Horizontal foot-candles				
Pedestrian traffic	Vehicular traffic classification with number of vehicles per hour in both directions			
	Very light (under 150)	Light (150-500)	Medium (500-1200)	Heavy to heaviest (1200 up)
Heavy	0.6	0.8	1.0	1.2
Medium	0.4	0.6	0.8	1.0
Light	0.2	0.4	0.6	0.8

Luminaires

A luminaire is the complete assembly of the light unit, including the series bayonet

receptacle, the series socket with film disk, the reflector or refractor, the lamp, and enclosing glassware if any.

The choice of the luminaire is governed by the mounting height, spacing, and transverse location of the fixture. Good practice requires that most of the light from a luminaire be directed toward the street, and be distributed to assure good utilization. Some light, however, should be directed back to the curb line to provide illumination on the sidewalk and adjacent areas or along the edges of piers. Incandescent and high-intensity mercury-vapor lamps are the most commonly used light sources. Sodium vapor is seldom employed because of its color, except for identifying a caution point at a street or road intersection.

Mounting Heights

In determining mounting heights for luminaires, the light should be kept as high as practicable to give greater and more uniform distribution of light. Overhead street lights, or lights located at street intersections, should be mounted between 22 to 25 feet high. For ornamental installations, where spacing is usually closer, this height may be reduced to 18 feet if overhanging luminaires do not conflict with street clearance requirements.

Control

Most street-lighting systems are automatically controlled by a time clock or photocell device. Systems with a single primary feed common to all transformers should be controlled by an automatic switch in the primary with the control switch in an attended station. When two or more transformers with separate primary feeds occur in the system, the control may be by relays operating on the cascade system or by carrier current.

INTERIOR WIRING

The first step in planning the circuit for any wiring installation is to determine the connected load per outlet. The load per outlet can be obtained in several different ways:

1. The most accurate method of determining load per outlet is made by obtaining the stated value from the blueprints or specifications. If the specifications are not available, the blueprints in many cases designate the type of equipment to be connected to specific outlets. Though the equipment ultimately used in the outlet may come from a different manufacturer, equipment standards provide the electrician with assurance that the outlets will use approximately the same wattage. If the equipment is available, the nameplate will list the wattage used or amperes drained. If not, data similar to that given in tables 2-3 and 2-4 should be obtained. Table 2-3 gives the average wattage consumption of electrical appliances, and table 2-4 lists the current requirements for small motors of various horsepower ratings.

2. To provide adequate wiring for systems where the blueprints or specifications do not list any special or appliance loads, the following general rules will apply:
   a. For heavy duty outlets or mogul size lampholders, the load per outlet should be figured at 5 amperes each.
   b. For all other outlets, both ceiling and wall, the wattage drain (load per outlet) should be computed at 1.5 amperes per outlet.

3. The total outlet load for general illumination may also be determined on a watts-per-square-foot basis. In this load-determination method, the floor area of the building to be wired is computed from the outside dimensions of the building. This square footage area is then multiplied by the standard watts-per-square-foot requirement based on the type of building to be wired. Table 2-5 lists these constants along with a feeder-demand factor for various types of building occupancies.

Maximum Load Demand Per Building

In some building installations the total possible power load may be utilized at the same time during daily operation. In this case, the generating capacity of the power supply, which must be kept available for these buildings, is equal to the connected load. In the majority of building installations where personnel will work, the maximum load which the system is required to service is much less than the possible total connected load. This power load which is set at some arbitrary figure below the possible total connected load is called the "maximum demand" of the building.

Table 2-3.—Wattage Consumption of Electrical Appliances.

Appliance	Average wattage
Blanket	150
Clock	3
Coffeemaker	550
Chafing dish	600
Dishwasher	100
Egg boiler	250
Fan, 8-inch	30
Fan, 10-inch	35
Fan, 12-inch	50
Frying pan	600
Griddle	450
Grill	600
Heater (radiant)	1000
Heating pad	50
Hotplate	660
Humidifier	500
Immersion heater	300
Iron	1000
Ironer	1320
Mixer	200
Phonograph	40
Range	8000
Refrigerator	250
Radio	100
Roaster	1320
Sewing machine	75
Soldering iron	200
Sunlamp	450
Television	300
Toaster	450
Vacuum cleaner	160
Washing machine	175
Water heater	2000
Waffle iron	660

Table 2-4.—Motor Currents.

Horsepower	Full-load amperes			
	120 v. 1 phase	240 v. 1 phase	208 v. 3 phase	416 v. 3 phase
1/6	3.1	1.6	...	...
1/4	4.4	2.2	...	...
1/2	7.1	3.6	2.1	1.1
3/4	9.8	4.9	3.0	1.5
1	12.5	6.3	3.7	1.9
1-1/2	17.7	8.9	5.3	2.7
2	23.1	11.6	7.0	3.5
3	32.6	16.3	9.6	4.8
5	54.0	27.0	16.0	8.0

Demand Factor

The ratio of "maximum demand" to possible total connected load in a building expressed as a percentage is termed "demand factor." The determination of maximum building loads (maximum demand) can be obtained by the use of standard demand factors as shown in table 2-5. For example, if the possible total connected load in a warehouse is 22,500 watts, using the demand factors listed in table 2-5 for warehouses, the maximum building load can be obtained as follows:

100 percent of the first 12,500 watts equal 12,500, 50 percent of the remaining 10,000 watts equals 500; therefore, the total maximum building load can be safely assumed to be 12,500 plus 5000 watts or 17,500 watts. This does not mean that the building load cannot exceed 17,500 watts; it can go as high as 22,500 watts. It only means that for this type building (warehouse) the maximum load which the wiring system is required to service is 17,500 watts.

Type of Distribution

The electrical power load in any building cannot be properly circuited until the type and voltage of the central power-distribution system is known. The voltage and the number of wires from the powerlines to the buildings are normally shown or specified on the blueprints. However, the Construction Electrician should check the voltage and type of distribution at the power-service entrance to every building in which wiring is to be done. This is especially necessary when the CE is altering or adding circuits. The voltage checks are usually made with an indicating voltmeter at the service-entrance switches or at the distribution load centers. The type of distribution is determined by visual check of the number of wires entering the building.

If only two wires enter the building, the service is either direct current or single-phase alternating current. The voltage is determined by an indicating voltmeter. At advance bases, two wires entering a building usually indicate single phase a-c.

When three wires enter a building the service is usually single-phase, or three-phase alternating current.

Table 2-5.—Standard Loads for Branch Circuits and Feeders and Demand Factor for Feeders.

Occupancy	Standard load, watts per square foot	Feeder demand factor, percent
Armories and auditoriums	1	100%
Banks	2	100%
Barber shops	3	100%
Churches	1	100%
Clubs	2	100%
Dwellings	3	100% for first 3,000 watts, 35% for next 117,000, 25% for excess above 120,000.
Garages	0.5	100%
Hospitals	2	40% for first 50,000 watts 20% for excess over 50,000.
Office buildings	2	100% for first 20,000 watts, 70% for excess over 20,000.
Restaurants	2	100%
Schools	2	100% for first 15,000 watts, 50% for excess over 15,000.
Stores	3	100%
Warehouses	0.25	100% for first 12,500 watts, 50% for excess over 12,500.
Assembly halls	1	100%

Grounding

A ground system is provided by installing a No. 8 wire protected in armor or conduit or a No. 6-gage bare wire connecting the nautral wire either to a water pipe or a driven pipe or rod used as a ground electrode. The wire is attached to the water pipe or conduit by a special clamp or bushing ground-connector clamp after the pipe or conduit has been filed or sandpapered clean to make a good electrical contact.

The National Electrical Code requires that on systems supplying interior wiring circuits, one wire of the circuit shall be grounded, provided that the voltage from any other conductor to ground will not exceed 150 volts on alternating currents systems.

Circuits operating at less than 50 volts need not be grounded, provided the transformer supplying the circuit is connected to a grounded system.

Wire Sizes

Wire sizes No. 14 and larger are classified in accordance with their maximum allowable current-carrying capacity based on their physical behavior when subjected to stress and temperatures of operating conditions. A 14-gage wire is the smallest wire size permitted for use in interior wiring systems.

The determination of wire size to be used in circuits is dependent on the voltage drop coincident with each size. The size of the conductor used as a feeder to each circuit is also based on voltage drop, and should be selected so that the voltage drop from the branch circuit supply to the outlets will not be more than 3 percent for power loads and 1 percent for lighting loads. Table 2-6, which is based on an allowable 3 percent voltage drop, lists the wire sizes required for various distances between supply and load, at the different amperages.

Table 2-6 also lists the service-wire requirements and capacities. The minimum gage for service-wire installation is No. 8 wire, except for installations consisting of a single branch circuit in which case they shall not be smaller than No. 12. Though this may seem to contradict the minimum wire size listed, the service-wire sizes are increased because they must not only meet the voltage-drop requirement

Table 2-6.—Voltage Drop Tables.

Wire size for 120-volt single phase circuit

Load (amps.)	Minimum wire size (AWG)	Service wire size (AWG)	Wire size (AWG) — Distance one way from supply to load (ft.) 50	75	100	125	150	175	200	250	300	350	400	450	500
15	14	10	14	12	10	8	8	6	6	6	4	4	4	2	2
20	14	10	12	10	8	8	6	6	6	4	4	2	2	2	2
25	12	8	10	8	8	6	6	4	4	4	2	2	2	1	1
30	12	8	10	8	6	6	4	4	4	2	2	1	1	0	0
35	12	6	8	6	6	4	4	4	2	2	1	1	0	0	2/0
40	10	6	8	6	6	4	4	2	2	2	1	0	0	2/0	2/0
45	10	6	8	6	4	4	2	2	2	1	0	0	2/0	2/0	3/0
50	10	6	8	6	4	4	2	2	2	1	0	2/0	2/0	3/0	3/0
55	8	4	6	4	4	2	2	2	1	0	2/0	2/0	3/0	3/0	4/0
60	8	4	6	4	4	2	2	1	1	0	2/0	3/0	3/0	4/0	4/0
65	8	4	6	4	4	2	2	1	0	2/0	2/0	3/0	4/0	4/0	
70	8	4	6	4	2	2	1	1	0	2/0	2/0	3/0	4/0	4/0	
75	6	4	6	4	2	2	1	0	0	2/0	3/0	4/0	4/0		
80	6	4	6	4	2	2	1	0	0	2/0	3/0	4/0	4/0		
85	6	4	4	4	2	1	1	0	2/0	3/0	3/0	4/0			
90	6	2	4	2	2	1	0	0	2/0	3/0	4/0	4/0			
95	6	2	4	2	2	1	0	2/0	2/0	3/0	4/0				
100	4	2	4	2	2	1	0	2/0	2/0	3/0	4/0				

Wire size for 220-volt three-phase circuits

Load (amps.)	Minimum wire size (AWG)	Service wire size (AWG)	Wire size (AWG) — Distance one way from supply to load (ft.) 100	150	200	250	300	350	400	500	600	700	800	900	1,000
15	14	12	14	12	10	8	8	8	6	6	6	4	4	4	2
20	14	10	12	10	8	8	6	6	6	4	4	4	2	2	2
25	12	8	10	8	8	6	6	6	4	4	2	2	2	2	1
30	12	8	10	8	6	6	6	4	4	2	2	2	1	1	0
35	12	8	10	8	6	6	4	4	4	2	2	1	1	0	0
40	10	6	8	6	6	4	4	4	2	1	1	1	0	0	2/0
45	10	6	8	6	6	4	4	2	2	2	1	0	0	2/0	2/0
50	10	6	8	6	4	4	2	2	2	1	0	0	2/0	2/0	3/0
55	8	6	8	6	4	4	2	2	2	1	0	2/0	2/0	3/0	3/0
60	8	6	6	6	4	2	2	2	1	0	0	2/0	3/0	3/0	4/0
65	8	4	6	4	4	2	2	2	1	0	2/0	2/0	3/0	3/0	4/0
70	8	4	6	4	4	2	2	1	1	0	2/0	3/0	3/0	4/0	4/0
75	6	4	6	4	2	2	2	1	0	2/0	2/0	3/0	4/0	4/0	
80	6	4	6	4	2	2	1	1	0	2/0	3/0	3/0	4/0	4/0	
85	6	4	6	4	2	2	1	0	0	2/0	3/0	4/0	4/0		
90	6	4	6	4	2	2	1	0	0	2/0	3/0	4/0	4/0		
95	6	4	6	4	2	1	1	0	2/0	3/0	3/0	4/0			
100	4	2	4	2	2	1	0	0	2/0	3/0	4/0	4/0			
125	4	2	4	2	1	0	2/0	2/0	3/0	4/0					
150	2	2	2	2	0	2/0	2/0	3/0	4/0						
175	2	1	2	1	0	2/0	3/0	4/0	4/0						
200	1	0	1	0	2/0	3/0	4/0	4/0							
225	0	0	0	0	2/0	3/0	4/0								
250	2/0	2/0	2/0	2/0	3/0	4/0									
275	3/0	3/0	3/0	3/0	3/0	4/0									
300	3/0	3/0	3/0	3/0	4/0										
325	4/0	4/0	4/0	4/0											

Table is based upon approximately 3% voltage drop.

but also be inherently strong enough to support their own weight, plus any additional loading caused by climatic and other conditions, such as ice, branches, and so on.

WIRING FOR HAZARDOUS LOCATIONS

Hazardous locations requiring special wiring considerations are divided into three classes by the National Electric Code.

Class I. For locations in which highly flammable gases and liquids are manufactured, used or handled, such as hydrogen, gasoline, alcohol, and so on, all wiring must be in rigid metal conduit with explosion-proof fittings. All equipment such as circuit breakers, fuses, motors, generators, controllers, and so on, must be totally enclosed in explosion-proof housings.

Class II. In locations where combustible DUST is likely to accumulate in the air in sufficient quantities to produce explosive mixtures, all equipment must be in dustproof cabinets with motors and generators totally enclosed or in totally enclosed fan-cooled housings.

Class III. Locations in which easily ignitible FIBERS or MATERIALS producing combustible flyings (particles suspended in the atmosphere) are handled or used, such as a woodworking shop or plant, require wiring of the same type as in Class II. If the atmosphere is such that combustible flyings will collect on motors or generators they must be enclosed as in Class II.

INSTALLATION IN HAZARDOUS LOCATIONS

The Code further specifies standards for particular types of installations. For example, some of these special requirements for hospital operating room installation are as follows:

All equipment installed in the operating room must be explosion proof and provided with a suitable equipment ground.

In locations used for anaesthetics, an underground electrical distribution system is required to reduce the hazards of electric shocks and arcs in the event of insulation failure. Alternating-current circuits shall be insulated from the conventionally grounded alternating supply by means of one or more transformers which isolate the circuits electrically from the main feeder line. Direct-current circuits shall be insulated from their grounded feeders by means of a motor generator set or suitable battery system.

All services equipment including switch and panel boards must be installed in nonhazardous locations.

Ceiling suspended lighting fixtures shall be suitably protected against mechanical injury.

Explosion-proof switches, receptacles, motors or similar conduit installations must be isolated from the rest of the conduit runs by sealed fittings. This type fitting has a removable plug which permits the insertion of a sealing compound, sealing off the points of possible explosion from the remaining conduit areas.

Nonmetallic tools such as rubber-head hammers and spark free drills must always be used when making electrical repairs or installations in the area.

PLANNING WORK FROM BLUEPRINTS

Whenever you are assigned a major project, you will normally be given a set of blueprints which will contain the plot or site plan, floor plans, electrical plans, and so on.

Your main concern will be the plot or site plan and all the prints dealing with the electrical phase of the project. You should also, however, study the complete set of plans so that you can coordinate your job with the jobs of the chiefs of the other ratings.

PLOT PLAN

The primary purpose of the plot or site plan is to show the exact location of the proposed project and the existing buildings, utilities, roads, contours, and other physical features in the vicinity (fig. 2-5). The plot plan shows you the existing gas line, sewer line, and the overhead power line. If you look at the plan closely you will also note that the power will be tapped from the overhead power source along the street in front of the building.

ESTIMATING FROM BLUEPRINTS

To estimate the amount of wire and electrical equipment you will need in any particular room or building, you will need an electrical sketch or plan similar to the one shown in figure 2-6.

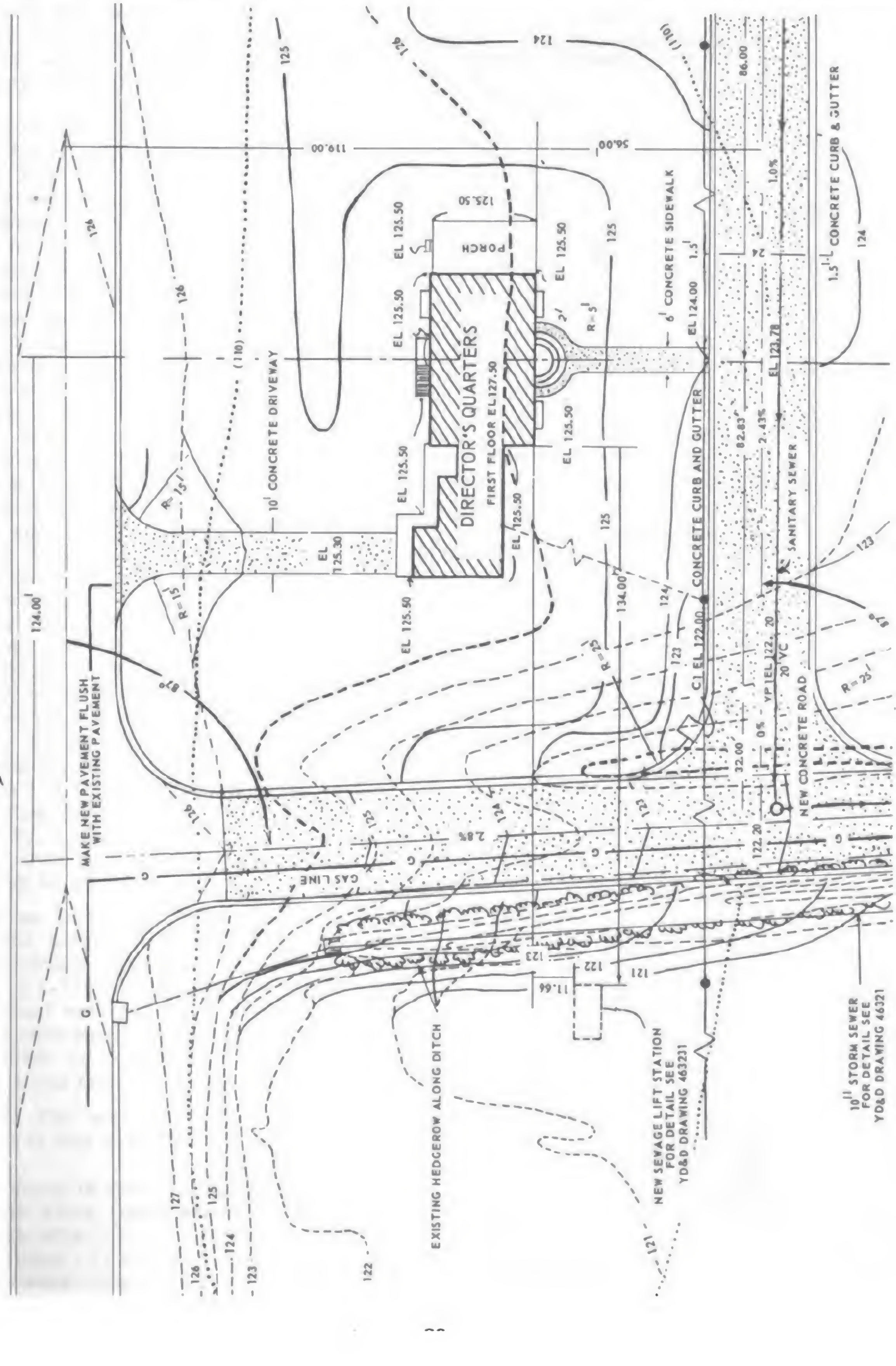


Figure 2-5. —Plot plan showing grading and drainage and drawing index.

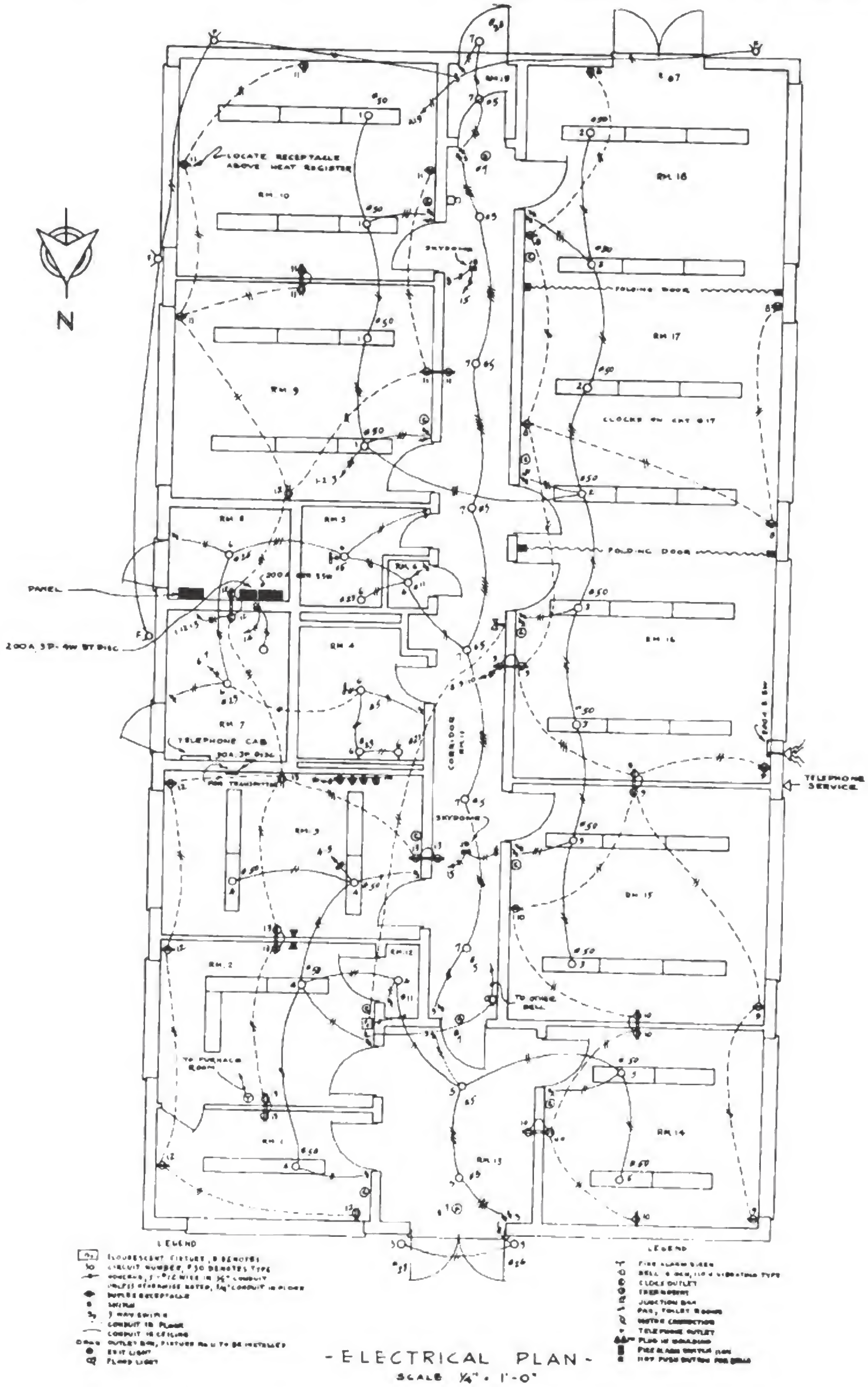


Figure 2-6. —Electrical plan.

26.6

Determining the amount of wire and electrical equipment required for a project is a time consuming and important part of your job, particularly when the bill of material is not given.

The best way to estimate the amount of wire and electrical equipment required is to start with the first circuit and trace it from the service panel or fuse box to the first outlet or switch, then on to the next, and follow that circuit through to the end. As soon as you complete tracing one circuit, go back and count the number of required receptacles, switches, outlets, junction boxes, and so on, and list them systematically on a separate sheet of paper. Then pick up circuit No. 2 and trace it through to the end, and again go back and count the electrical equipment required. You will continue this for all circuits. In estimating the amount of wire required, you must add 1 foot of wire at each connection; this means that every run of wire will require 2 extra feet of wire, 1 extra foot at each end. Also, to be sure that you do not miss any circuit or branches, it is advisable to use a colored pencil to trace over each branch circuit as you cover it.

To get some actual practice in electrical estimating, refer to figure 2-6 and trace the No. 1 lighting circuit. The No. 1 lighting circuit located in rooms 9 and 10, and the wires for this circuit are placed in the conduit which is located along the ceiling.

The electrical plan shown in figure 2-6 is scaled to 1/8 inch equals a foot.

Beginning with the No. 1 circuit, (actually circuits No. 1, 2 and part of circuit No. 3.) use a scale or rule and measure directly from each point listed below:

1. From homerun symbol (arrow pointing back to the service entrance switch) at ceiling outlet northwest of room 9 to service panel (room 8) is 1-7/8" or 15' plus 2' plus 3' (The 3' is the amount required to be run from the ceiling to the service panel, which is normally located at eye level or 5 feet from the floor, which would be 3 feet from the ceiling.)

NOTE: The plan indicates that there are five wires in this conduit.

The amount of wire required is:
2 white wires (neutrals). 30' + 4' + 6' = 40'
1 black wire. . . . . 15' + 2' + 3' = 20'
1 red wire . . . . 15' + 2' + 3' = 20'
1 blue wire. . . . . 15' + 2' + 3' = 20'

2. From northwest ceiling outlet room 9, to switch in same room is 1/2" or 4'.

NOTE: The plan indicates there are three wires.

The amount of wire required is:
3 black wire . . . . 12' + 6' + 12' (ceiling to switch 4') = 30'

3. From northwest ceiling outlet in room 9 to southwest ceiling outlet in same room is 7/8" or 7'.

NOTE: The plan indicates there are three wires.

The amount of wire required is:
1 white (neutral) . . 7' + 2' = 9'
2 black wires . . . . 14' + 4' = 18'

4. From southwest ceiling outlet of room 9 to northwest ceiling outlet of room 10 is 15/16" or 7 1/2'.

NOTE: The plan indicates there are 2 wires.

The amount of wire required is:
1 white wire (neutral). 7-1/2'+ 2' = 9-1/2'
1 black wire . . . . . . .7-1/2' + 2' = 9-1/2'

5. From northwest ceiling outlets, room 10 to switch in same room is 9/16" or 4-1/2'.

NOTE: The plan indicates there are three wires.

The amount of wire required is:
3 black wires . . 13-1/2' + 6' + 12' (4' ceiling to switch) = 31-1/2'

6. From northwest ceiling outlet in room 10 to southwest ceiling outlet in same room is 7/8" or 7 feet.

NOTE: The plan indicates there are two wires.

The amount of wire required is:
1 white wire . . . 7' + 2' = 9'
1 black wire . . . 7' + 2' = 9'

To total up the number of feet of the various color wire required, you may proceed thusly:

Measure-ment number	white wire	black wire	red wire	blue wire	conduit
1	40'	20'	20'	20'	18'
2	0	30'	0	0	8'
3	9'	18'	0	0	7'
4	9 1/2'	9 1/2'	0	0	7-1/2'
5	0	31 1/2'	0	0	8-1/2'
6	9'	9'	0	0	7
TOTAL . .	67-1/2'	118'	20'	20'	56'

In order to make allowances for going around some unaccounted obstruction, and also for inaccuracies in measurement due to shrinkage in blueprint paper when making reproduction, you must add 10 percent. For example, you would actually need 129.8' of black wire; 118' x 10%, would give you 11.8. Add this to 118' and you would get a total of 129. 8'.

Besides the wire and conduit you must determine the amount of wire nuts, switch boxes, switches, outlet boxes, conduit straps for holding conduits (usually 1 for every 5 feet of conduit), bushings and locknuts for conduits, and finally lighting fixtures and wall plates for the switches.

LAYING OUT THE JOB

Now that you have determined the amount and type of material you will need on the project, you need to study the blueprints further to determine the type of construction so that you can schedule your work properly.

The electrical plan shown in figure 2-6 is for a structure having a concrete deck, and brick on concrete block with 2-1/8 inch air space between the walls. In scheduling your work you must move your crew on to the job after the equipment operators dig the footings and level the foundation, and immediately after the steelworkers place the reinforcing rods. Your crew must then properly place all necessary conduit that is specified on the electrical plan. It will be necessary for you to cooperate with the chiefs of the other rates to avoid any unnecessary delays.

INSTALLATION SCHEDULE (TIME)

If you are to schedule your work with any degree of accuracy, you must be able to estimate how long it will take your men to complete each phase of the job.

Because the amount of work performed by an individual depends on many factors including climate, type of work, equipment available, ability, experience, interest, and many others, productivity rates vary from time to time and place to place. **The norms shown in table 2-7 are averages and have been adapted to the** field type construction associated with advanced base construction.

Adequate supervision by the crew chief, and the importance of the ingenuity and resourcefulness of the crew members, should not be underestimated. This table is only to serve as a guide; after you get to know your crew you can probably determine the installation time more accurately.

TESTING AND INSPECTING

After the construction work is finished you still have two more responsibilities. One is testing the entire circuit; the other is getting the job inspected. Testing the circuit consists of checking for grounds, shorts, and opens, and also testing the resistance value of the insulation, splices, insulators, and so forth.

Inspection consists in getting your work approved by the officer-in-charge of the project. He will check the splices, connections, workmanship, and very likely will insist that the insulation tests be conducted in his presence. He will require that you accompany him on his tour of inspection. So be prepared to answer any questions he may ask.

Table 2-7.—Construction Norms for Electrical Work.

Complete installation for outlet (Roughing for box, conduit, wiring and connections)	Complete Unit Per Man-Day		
	Minimum Acceptable	Average	Outstanding Performance
With Armored Cable or 1/2" flexible conduit.	4	8	12
With Rigid Conduit, all sizes	3	5	7
Installing Outlet Boxes	Units Per Man-Day		
Ceiling and wall outlet boxes	20	25	30
Service switches & base plugs	25	35	55
Meter, fuse box, switch box, etc.	4	6	8
Installing Rigid Conduit & Connect	Linear Feet Per Man-Day		
1/2" and 3/4"	50	70	80
1" and 1-1/4"	45	55	65
1-1/2" and 2"	30	40	50
Installing 1/2" Flexible Conduit	100	150	200
Pulling and Installing Wire in Conduit			
#8 to #14 gage	400	500	600
#1 to #6 gage	150	250	350
Installing Armored Cable	100	150	200
Installing and Wiring Fixture	Units Per Man-Day		
Ceiling or Wall Light	9	14	20
Switch, Base or Fuse Plug	20	25	30

CREW PATTERN: - Two Electricians for each crew.

PRODUCTIVITY: For a building with 1000 linear feet of 1/2" and 3/4" rigid conduit; 76 outlets; 21 light fixtures; 25 switches; a meter, fuse, and switchbox; it will take 24 man-days to completely install the electrical work, computed as follows:

INSTALLATION OF:

76 outlets at 4 per man-day	19.0	Man-Day
Meter, fuse and switchbox at 6 per man-day	.5	
21 light fixtures at 14 per man-day	1.5	
25 switches at 25 per man-day	1.0	
Miscellaneous and Test	2.0	
	24.0	Man-Days

NOTE:
The prefabrication of the rigid conduit will increase productivity.

CHAPTER 3

CONTROLLERS AND PROTECTIVE DEVICES

Protective devices and controllers are standard equipment for all electrical systems. Operating, servicing, or troubleshooting controllers and protective devices range from simple tasks such as changing a fuse to complex jobs such as determining whether an automatic voltage regulator is operating properly. These and many other jobs are necessary if proper electrical service is to be maintained within an electrical system.

PROTECTIVE DEVICES

The function of any protective device is to protect life and equipment. Generally speaking, protective equipment is designed to interrupt the flow of electricity in a circuit when operating conditions become dangerous. Fuses and circuit breakers are the main types of electrical protective devices.

FUSES

As you know, the simplest overload protective device is a fuse. The principle of fuse operation and a few common types of fuses are described in Basic Electricity, NavPers 10086-A, and in Construction Electrician 3 & 2, NavPers 10636-D. In this chapter, we shall discuss other types of fuses.

High-Voltage Fuses

High-voltage fuses are used at substations to provide back-up protection for the low-voltage feeder breaker and to prevent a transmission line outage on faults occurring within the substation ahead of the low-voltage breaker or feeder fuses.

For substations up to the 69-kv class having transformer capacity limited to 5,000 kva or less, fuses combined with gang-operated airbreak switches are safe and reliable and may be used for transformer protection. The cost of installing and maintaining fuses and airbreak switches is less than comparable costs for oil circuit breakers. The added maintenance cost of replacing fuses is more than recovered in reduction of costs chargeable to inspection and maintenance of oil circuit breakers, relays, and battery control circuits. One disadvantage of fuses is that they may single phase. This may cause partial or total interruption of service. There is no possibility of single phasing with an oil circuit breaker.

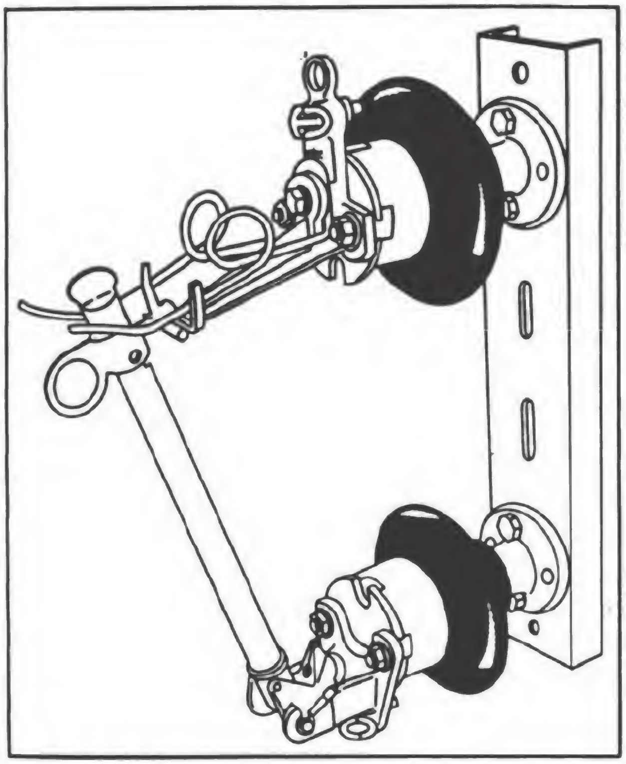
When re-fusing gang-operated airbreak switches, greater safety is ensured with the installation of a gang-operated grounding device that grounds both sides of the fuse. If such a device is not warranted, ordinary ground sticks should be accessible for use at all times. A fusing platform may be used to enable the operator to replace fuses that are mounted too high in the structure or too close to high-voltage equipment for safe fuse-stick operation from the ground.

Expulsion Type Fuse

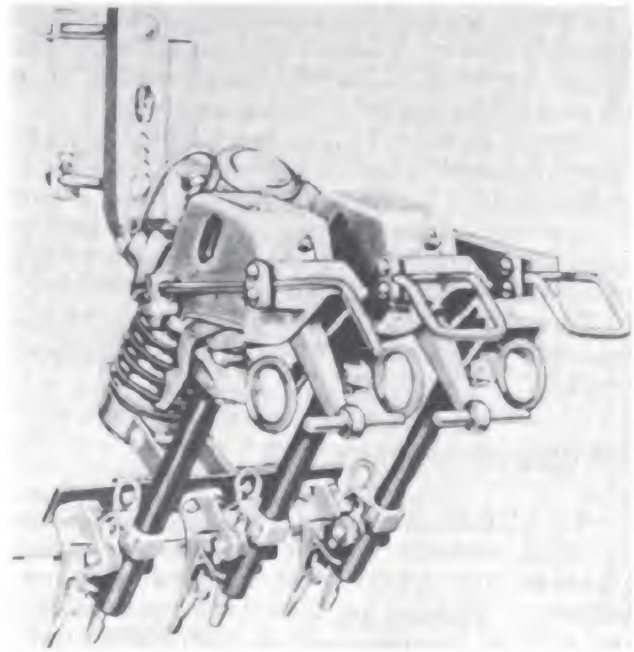
The expulsion fuse shown in figure 3-1 is an open cutout or disconnect fuse. It has a universal tension type fuse link. When the fuse link melts, current is made to flow through the thin stranded wire. The current instantly melts the wire and removes tension on the spring thereby causing the fuse terminal to separate.

Repeating Cutout Fuse

The repeating cutout fuse shown in figure 3-2, has three fuse tubes mounted so that when the first fuse "blows," it trips the second fuse into the circuit. If the fault continues the second fuse trips in the third. This arrangement allows clearance of temporary faults and promptly restores service by the automatic circuit reclosing action of the second and third fuse if necessary. This type of fuse assembly is almost exclusively applied in outdoor distribution circuits.



26.7
Figure 3-1.—Outdoor open type cutout fuse (expulsion) 7,500 volts, 100 amperes.



26.8
Figure 3-2.—Automatic reset repeating cutout, 15,000 volts, 100 amperes.

Other Fuses

Other types of fuses are the BORIC ACID FUSES, LIQUID FUSES, and DRY TYPE CURRENT-LIMITING FUSES. In the boric acid fuse, a malfunction in the circuit produces steam which interrupts the flow of current. This type of fuse can be mounted with small clearances; there is no visual indication that the boric acid fuse has blown.

One common form of liquid fuse is the oil-filled cutout, in which the fusible element is submerged in oil and is generally mounted on a circulating or rotating frame so that by moving an external handle the circuit can be interrupted. This type of fuse is generally used in underground systems.

There are two kinds of dry type current-limiting fuses: the single and the double element type. These fuses operate on the principle of melting the fuse far in advance of the possible peak current of the first half-cycle. The fuse is designed in such a manner that the melting process introduces a high arc resistance, which, in turn holds the circuit current within the rating of the fuse.

FUSE MAINTENANCE

Fuse maintenance consists of inspecting mountings and supports, and checking for broken insulators and mechanical defects. Replace without delay broken or cracked insulators and repair or replace, as necessary, parts that are defective. Routine inspections should always include:

1. Checking fuses for correct rating and ensuring that fuse tubes are capped securely to exclude dust and water.
2. Replacing warped, broken, scorched, or burned tubes.
3. Keeping fuses with dropout and repeating features in good condition and free from foreign matter. Check them for proper operation by trial on routine fuse changes, or when the transformer bank is deenergized for other purposes.

CIRCUIT BREAKERS (GENERAL)

Circuit breakers are generally used at substations and at junction points of important circuit or lines to switch transformers in or out of circuits and to sectionalize lines.

Circuit breakers, like fuses, automatically open the circuit whenever the current exceeds a predetermined value, either because of a fault or overload in the circuit. After being tripped open, the circuit may be closed manually or may be automatically reclosed after a short delay.

There are two general types of circuit breakers, the air circuit breaker and the oil circuit breaker.

AIR CIRCUIT BREAKERS

Air circuit breakers are so called because the main contacts open in the air. Air circuit breakers are normally used on switchboards, switchgear groups, and distribution panels. They are seldom, if ever, used on distribution lines. When operated electrically, the operation is usually in conjunction with a pilot device such as a pressure switch. Electrically operated circuit breakers employ an electromagnet, used as a solenoid, to trip a release mechanism that causes the breaker contacts to open. The energy to open the breaker is derived from a coiled spring. The electromagnet is controlled by the contacts of the pilot device.

Circuit breakers designed for high currents have a double-contact arrangement. The complete contact assembly consists of the main bridging contacts and the arcing contacts. All current carrying contacts are high-conductivity, arc-resisting silver or silver alloy inserts.

Each contact assembly has a means of holding the arcing to a minimum and extinguishing the arc as soon as possible. The arc control section is called an arc chute or arc runner. The contacts are arranged so that when the circuit is closed, the arcing contacts close first. Proper pressure is maintained by springs to ensure that the arc contacts close first and that the main contacts follow.

When the circuit opens, the main contacts open first. The current then flows through the arc contacts; this prevents burning of the main contacts. When the arc contacts open, they pass under the front of the arc runner. This causes a magnetic field to be set up, which blows the arc up into the arc quencher and quickly opens the circuit.

OIL CIRCUIT BREAKERS

The typical oil circuit breaker consists of one or more metal tanks filled with insulating oil and metal caps attached to the top of the insulating bushings. Conductors or copper rods attached to stationary contacts located below the oil level in the tanks pass through the metal caps. The stationary contacts are bridged by movable contacts. The movable contacts are operated by an external or an internal source. When the breaker is closed, the movable contacts complete the circuit. When the circuit is open, they are displaced from the bridging position.

Installation

Circuit breakers are normally mounted and controlled in one of the following ways.

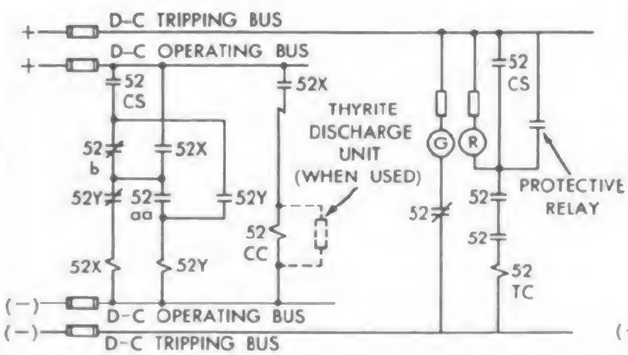
1. Directly on a switchboard with manual closing and opening and with automatic electrical tripping.
2. Remote from a switchboard with manual closing and opening and with automatic electrical tripping.
3. Remote from a switchboard with electrical closing and opening and with automatic electrical tripping.

Closing mechanisms are of the solenoid type, the centrifugal-motor type, or the pneumatic type.

Energy for opening and closing oil circuit breakers, operated manually or by automatic remote control, may be supplied from one or more of the sources shown by the control diagrams in figures 3-3, 3-4, and 3-5.

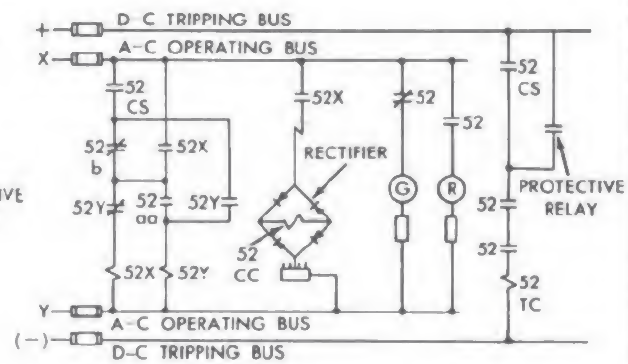
MAINTENANCE AND INSPECTION OF POWER CIRCUIT BREAKERS

Procedures for inspecting and overhauling oil circuit breakers depend largely on the nature of service and the type of apparatus used. Make inspections at least twice a year and oftener if necessary. When a circuit breaker normally remains in an open or closed position over extended periods of time, operate it periodically for two or three opening and closing cycles to make sure that parts are in working order and properly lubricated. Such tests can usually be made at times when intermittent interruptions of power will not interfere with



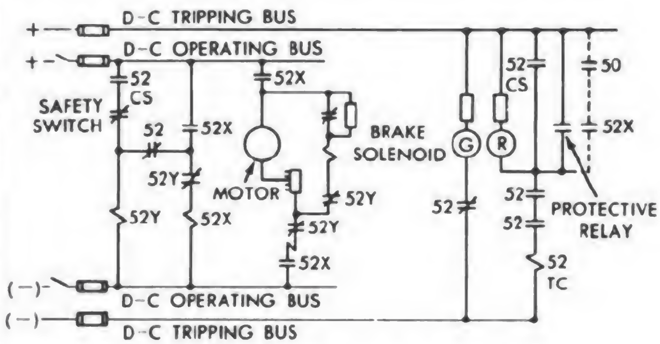
TYPICAL ELEMENTARY DIAGRAM OF D-C SOLENOID MECHANISMS

(A)



TYPICAL ELEMENTARY DIAGRAM FOR A-C RECTIFIER-SOLENOID MECHANISMS

(B)



TYPICAL ELEMENTARY DIAGRAM OF TYPE ME-10 MOTOR MECHANISMS FOR FH OIL-BLAST CIRCUIT BREAKERS

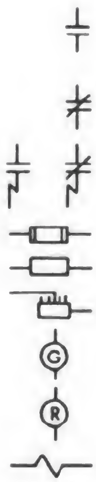
(C)

NOTES

1 CONVENTION HAS DEVELOPED, AND NEMA HAS STANDARDIZED, NUMBERS FOR SWITCHGEAR DEVICES. FOR CONVENIENCE OF REFERENCE AUXILIARIES AND ATTACHMENTS ARE INDICATED BY LETTERS APPENDED TO THE DEVICE NUMBERS. THE FOLLOWING SYMBOLS, DEVICE NUMBERS, AND LETTERS ARE USED IN FIGURES (A) (B) AND (C).

2 FOR SIMPLICITY, TERMINAL BOARDS, AUXILIARY SWITCHES NOT CONNECTED IN THE CONTROL CIRCUITS, AND ALSO KNIFE SWITCHES USED IN THE CONTROL CIRCUITS OF MANY OF THE LARGE BREAKERS, ARE OMITTED FROM THE TYPICAL DIAGRAMS IN FIGURES 69 AND 70.

LEGEND



=CONTACT OPEN WHEN DEVICE IS OPEN, OR IN DEENERGIZED OR NONOPERATED POSITION.

=CONTACT CLOSED WHEN DEVICE IS OPEN, OR IN DEENERGIZED OR NONOPERATED POSITION.

=CONTACTS WITH BLOWOUT COIL.

=FUSE

=FIXED RESISTOR

=TAPPED RESISTOR

=GREEN INDICATING LAMP

=RED INDICATING LAMP

=COIL OR WINDING

50=SHORT-CIRCUIT SELECTIVE RELAY, USED WHEN THE RMS AMPERES IN FIRST CURRENT LOOP (FIRST CYCLE) OF SHORT CIRCUIT, DURING CLOSING OPERATION OF CIRCUIT BREAKER, MAY EXCEED THE MAXIMUM INTERRUPTING CURRENT OF THE BREAKER.

52=POWER CIRCUIT BREAKER (NOT SHOWN).

52X=CLOSING RELAY OR DEVICE FOR 52.

52Y=CUTOFF RELAY OR ANTIPUMP DEVICE FOR 52.

52CS=CONTROL SWITCH FOR 52.

52CC=CLOSING COIL FOR 52.

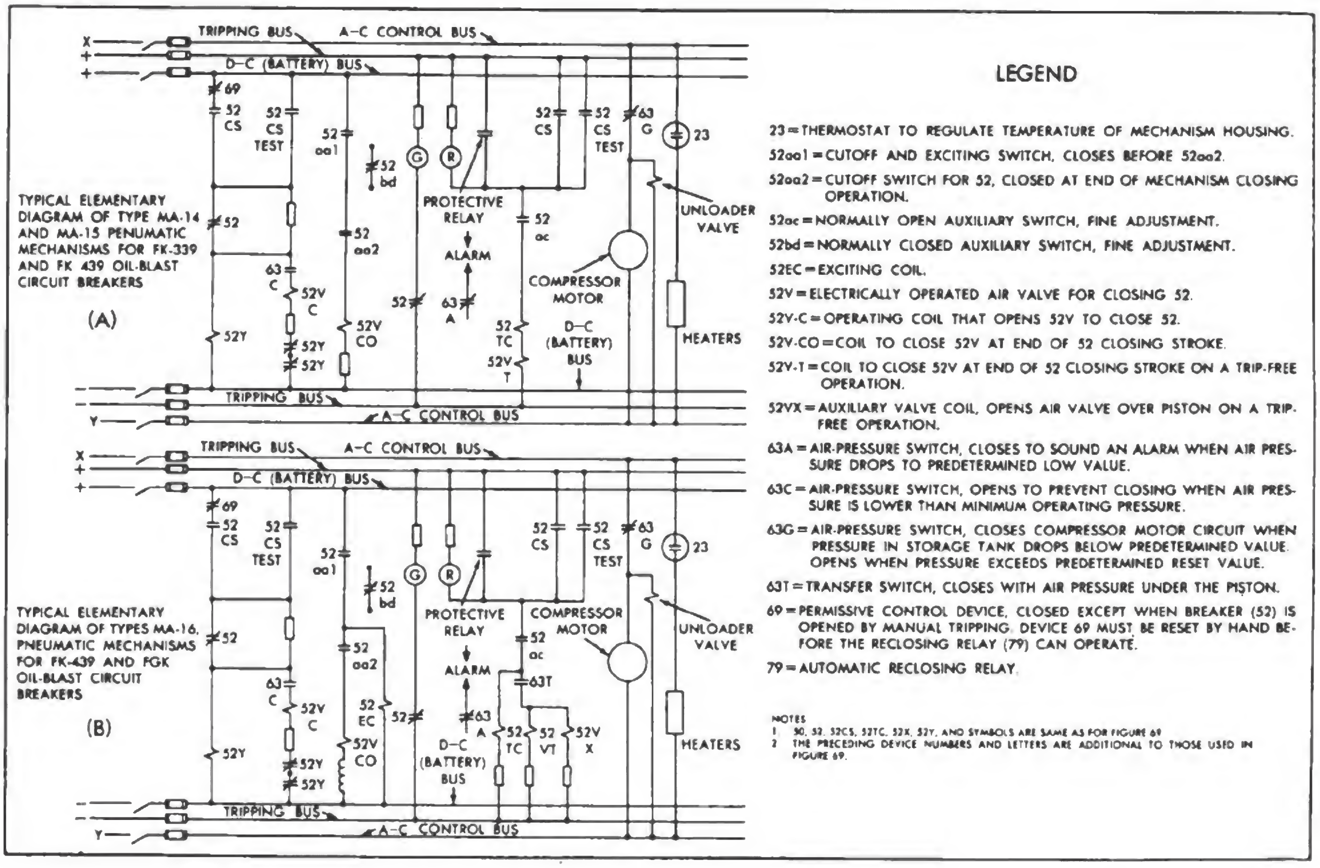
52TC=TRIP COIL FOR 52.

52aa=CUTOFF AUXILIARY SWITCH FOR 52, CLOSED AT END OF MECHANISM CLOSING OPERATION.

SAFETY SWITCH HOLDS OPEN THE CLOSING CIRCUIT WHEN MAINTENANCE CLOSING DEVICE IS IN PLACE

26.9

Figure 3-3.—Typical connection diagrams of electrically operated oil circuit breakers.



26.10

Figure 3-4.—Typical connection diagrams for pneumatic mechanisms for outdoor oil blast power circuit breakers.

normal operation; make them during periods of light load if the breaker is in normally closed service for extended periods. Make an inspection after a breaker has opened to clear a severe fault. OVERHAUL AT LEAST EVERY 2 YEARS, preferably in the spring of the year. Recommended procedures for making periodic overhauls are described in the following paragraphs.

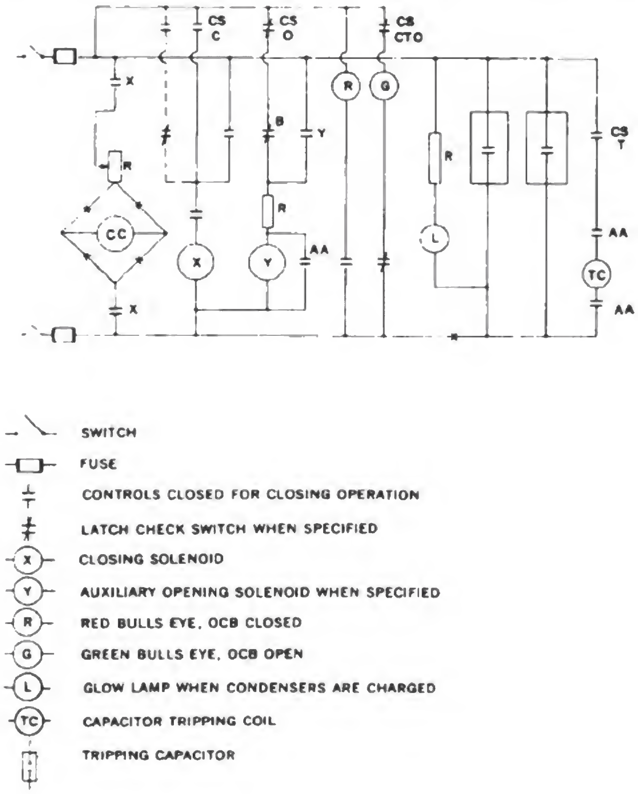
Preliminary Procedure

Make arrangements in advance with the electrical superintendent to take apparatus out of service. After the breaker is opened, check for positive grounding. The man in charge of the crew must check to be sure the apparatus is deenergized and safe for personnel to handle. The disconnect switches should be opened to isolate the oil circuit breaker completely from any possible source of energy. If one or more potential transformers are used in connection with the oil circuit breaker and they are connected to the oil circuit breaker side of the disconnecting switches, the fuses on the primary side of these potential transformers are removed. After this switching is completed, the proper tags are placed on the oil circuit breaker controls.

To prevent accidental contact by personnel, place suitable barriers around adjacent apparatus that might still be energized. In crowded installations, barriers may be of rope or net with suitable danger flags, or of temporary rigid insulated material.

Equipment to be worked on must first be deenergized, (both sides of the circuit broken), then grounded. To perform these operations safely, personnel should always use:

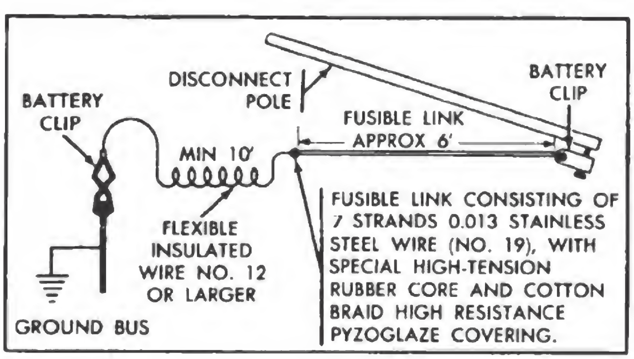
1. Rubber gloves
2. Safety goggles



26.11

Figure 3-5.—Typical connection diagram of capacitor trip, solenoid close oil circuit breakers.

3. An approved voltage detector. A voltage detector may be made from a length of insulated wire, equivalent to No. 12 wire or larger, with a 6-foot fusible link consisting of No. 19 special high-tension wire fastened to a disconnect pole. (See fig. 3-6.)



26.12

Figure 3-6.—Diagram of a voltage detector.

GROUNDING CABLE.—A No. 2, or larger grounding cable should have a suitable clamp on one end for making connection to a ground bus. On the other end hot-stick clamps should be provided for connection to metallic terminals of apparatus. (See fig. 3-7.)

Neither adjustments nor replacement of circuit breaker parts should be attempted without first consulting the manufacturer's instruction manual.

Testing and Grounding

The following is the recommended procedure for testing and grounding:

1. Connect one end of an insulated test wire to the ground bus and fasten the other end to the disconnect pole.
2. Wearing rubber gloves and goggles, touch each metallic terminal of the bushings with a test cord. After touch-testing the apparatus, remove the test wire.
3. Connect one end of each grounding cable to the ground bus, and apply the hot stick clamps on the other end of the cable to each metallic terminal of the bushings of the oil circuit breaker. Whenever a circuit or a piece of equipment is grounded out for the protection of personnel, some means must be provided for tagging the point of grounding so that other personnel will understand that the ground should not be removed until maintenance work is completed. Various means may be used. Brilliantly colored tags large enough to be seen from a considerable distance are suitable as are flags that may be hung or clipped to the equipment. Station maintenance practices prohibit the removal of switching or grounding tags without the knowledge and consent of the individual who placed them. This is a safety practice that must be rigidly adhered to.

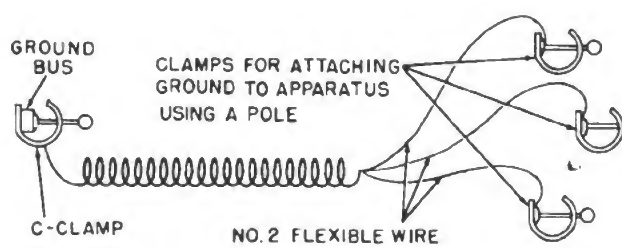


Figure 3-7.—Grounding cable. 26.13

Isolating Controls

To isolate the closing and tripping control and to prevent inadvertent operation of the oil circuit breaker, the switch in the operating control circuit must be opened. If there is no switch in the operating control circuit, block the closing relay in the open position and disconnect the trip coil from the circuit, thus making the oil circuit breaker inoperative from any remote-control station.

Lowering and Removing Tanks

Place a pan under the breaker before lowering the tank, to catch any oil spill. Larger breakers usually have tank lifters for lowering the tanks; on smaller breakers, the tanks are lowered by hand. When using a tank lifter, take some tension on the lifting cables or platform to take the load off the bolts while they are being removed. Then remove the tank bolts and lower the tank to the pan on the floor or pad. When the tanks have been lowered, the following routine is recommended: Allow the mechanisms to drain for a few minutes before removing the tanks, and operate the breaker by hand to force oil out of the contacts. Do not trip free unless the contact mechanism is immersed in oil; this prevents injury to buffer springs, insulators, and so on. Release the breaker and let it out slowly by the hand-operating lever. After this has been done, wipe the interiors of the mechanisms dry with lint-free wiping rags. Then remove the tanks from beneath the breaker and filter the oil.

Tank Liners

The next step is to drain the tanks and remove the liners. Clean the tanks and liners with lint-free rags. If the liners are of the paper-composition type, check them carefully for moisture. Although paper liners do not absorb oil, they readily absorb any water that gets into the oil and ultimately cause the liners to separate and become soft and pliable. If a liner contains moisture, dry it in an oven before replacing it in the tank. If a liner has a metal ring around the top, check the bonding between the metal ring and tank. The ring must make positive contact with the tank metal.

Inspection of Contacts

Check contacts and arc tips for burning, mechanical defects, and so on. Although the main contacts should not show signs of burning, an arc sometimes carries over from the arc tips to the main contacts during a violent tripout. Check to see that breaker contacts are properly aligned and that contact surfaces bear against one another, with uniform, firm pressure and are adjusted in accordance with the instruction book. Replace badly pitted or burnt-out contacts, but smooth down with a clean fine file those that are only roughened. (This does not apply to silver contacts.) When a device contains both main and arcing contacts, the main contacts require little maintenance, but should be inspected regularly and kept smooth and clean.

Replace arcing contacts if they are badly pitted or burned or when their dimensions fall below minimum requirements. This will assure their continuing to protect the main contacts from arc damage. Finger-type contacts normally require more maintenance than butt contacts. An indication of excessive arcing is the decrease in thickness of the contact metal below the minimum thickness required for proper operation as stated in the instruction book. Most manufacturers state the minimum thickness of metal required for proper operation. Although some adjustment is provided, there are limitations beyond which operation will not be satisfactory.

Contacts on interrupters, such as those used on certain oil-blast breakers, require proper alignment and uniform pressure.

Radial-blast interrupters and cross-blast interrupters use butt contacts, with their arcing and current-carrying functions being performed by the same set of contacts. These are high-pressure type interrupters, and it is not necessary to dress or smooth their contact surfaces. However, such contacts are gradually burned away by arcing and must be adjusted at intervals and replaced eventually to maintain proper contact. Approximately three-thirty-seconds of an inch can be burned off the upper and intermediate contacts before they demand replacement. The contact rod tip can be burned off to a stub too short to make contact without encroaching on required clearance between the bottom of the interrupter and the contact crossarm.

The main contacts of cross-blast interrupters require little attention except periodic

checks for proper alignment and adjustment and to assure that they are kept smooth and clean.

Replace arcing contacts as in any other interrupting device when they become badly pitted or burned. Keep the contacts of magnetic air-blast breakers clean and bearing with uniform pressure in the same way as other contact surfaces. When proper contacts cannot be maintained, or the alloy turns back far enough so that the arc is destroying the copper, replace the contacts. In air-blast breakers, make periodic inspections to ascertain that no excessive wearing or scoring has taken place on the surfaces of the wiping contacts. If they are badly scored or pitted, replace them. A good indication of the condition of the contacts within the arc chute can be made by inspecting the arcing tips on the moving contact blades. If these are badly pitted or burned, it is probable that the internal contacts are in the same condition. Severely burned contacts or fibers in the chute indicate need of replacement.

Oil

Test oil in service at frequent intervals (3-month intervals are recommended) or after each operation at or near breaker rating. If oil shows signs of moisture, carbonization, or dirt, filter and test it with a standard spark gap oil tester. If the dielectric strength of the oil tests less than 22,000 volts as measured by standard disks in the tester spaced 0.1 inch apart, keep filtering the oil until the proper dielectric strength is reached. The dielectric strength of new oil should be 26,000 volts minimum. Keep the oil in the tanks at the proper level, and check the oil gage to make certain that it is indicating properly. Check all oil valves to see that they do not leak. Also, check the condition of all gaskets to make sure that they seal properly to prevent entrance of moisture and leakage of oil.

Bushings

Clean the external surfaces of bushings to remove dirt or other deposits. Where abnormal conditions prevail, clean bushings frequently to reduce possibility of flashover. Warm water and soap are recommended for cleaning most bushings; if soap is not available, an approved Navy solvent may be used; take care to avoid spilling the solvent on parts that could be injured by it. Check the bushings to make sure that they have not moved from the proper positions on account of vibration or other causes. Check porcelains for cracks or breakage, and note the level of oil in oil-filled bushings to make sure that it is at the proper level.

Internal Insulating Parts

Clean all surfaces of the bushings and other insulating parts inside the tanks to remove traces of carbon or sludge that may remain after the tanks have been drained. Clean all internal parts of breakers before new filtered oil is added.

Keep insulating parts of magnetic air-blast breakers clean and dry. Wipe off dust, carbon or other foreign matter collected on magnetic air-blast breakers between inspection periods and, if there is evidence of dampness, install heaters in the compartment to ensure dryness. Scale that develops on the insides of arc chutes should be left intact, but loose scale in the muffler portions of the devices should be cleaned out to prevent malfunction of the arc.

Porcelain air-line insulators (if any) in the rear of the arc chutes in air circuit breakers should be wiped out and inspected for mechanical damage. Remove these insulators at least once a year and inspect for damage; then clean them internally with suitable solvents. Remove any accumulation of carbon or dirt.

Breaker Mechanism

The breaker mechanism should operate smoothly and freely without stiffness or binding. Lubricate all bearing surfaces with the lubricant recommended by the manufacturer of the circuit breaker. Ascertain that all cotter pins have been opened after insertion and that all snap rings, locking plates, nuts, and so on are in place and properly tightened. Check the stop clearance against the value given in the instruction book and adjust it if necessary. Inspect oil-filled dashpots and fill them with the same type and grade of oil as specified for the breakers with which they are used. The length of the breaker stroke and its opening and closing speeds should be measured, checked, and adjusted in accordance with directions contained in the instruction book. Make certain that the operating

rod for moving the contacts does not bind against its guide. Check also for broken or distorted springs.

Operating Mechanism

Lubricate the mechanism in accordance with the instruction book and see that it operates freely throughout its entire stroke. Make parts that are scored or show excessive wear conform to tolerances listed in the instruction book. Ensure that the operating voltage at the mechanism terminals, with full operating current flowing, is adequate for correct operation. This is especially important for solenoid-operated mechanisms. Check the air pressure on pneumatically operated mechanisms to assure that it is adequate and that it is restored promptly after each breaker operation. Inspect air connections or piping for possible leaks and broken or distorted springs. In addition, make the following routine checks:

1. Closing relay and its contacts.
2. Tripping arrangement for positive tripping, including auxiliary switch adjustments and contacts. Dress or replace damaged contacts.
3. Pneumatically operated mechanisms. Check all electrically operated valves; keep the air system clean by periodic replacement of compressor filter pads, by regular blowing off of water condensation, and by systematic overhaul and cleaning of the air strainer, check valve, unloader, and other critical parts that collect dirt. Check the adjustment of all pressure switches and lockout devices. Refer to the instruction book for proper pressures.

Check all cotter pins, locking plates, snap rings, and nuts for tightness.

Auxiliary Equipment on Mechanism

The operating mechanism on an oil circuit breaker employs an auxiliary multiple-pole switch for making-and-breaking, closing, tripping, and position-indicating circuits. The following is the recommended inspection procedure.

1. Check all auxiliary switch contacts to see that they operate freely and make good contact. Burns sometimes occur on heavily loaded contacts, such as those for large trip coils. In such cases, remove relays if necessary to clean the contacts with fine sandpaper.
2. Check all electrical connections to the breaker mechanism and auxiliaries to see that they are tight and making good contact. Check and clean contacts and arc chutes on the auxiliary closing relay for operating the closing coil. Inspect and oil all bearings.
3. In the case of a motor-operated mechanism, inspect all electrical connections, motor bearings, and brushes, as well as all other moving parts. The speed of the closing motor is usually controlled by a variable resistor that is in series with the motor and can be adjusted for seasonal climatic changes or for adaptation to a larger or smaller circuit breaker. For further information, refer to manufacturer's instruction manual.

Troubleshooting

Table 3-1 shows the common troubles encountered in power circuit breakers and gives the causes and remedies of each.

CONTROLLERS

A controller regulates the operation of electrical equipment. A controller for electric motors is simply a starter which provides a convenient and safe means of performing several or all of the following functions:

1. Start and stop
2. Accelerate and decelerate
3. Regulate the speed
4. Reverse

In some applications the motor must be frequently started, stopped, and reversed, in addition to having its speed varied continually. Some a-c motor controllers stop motors quickly by plugging. Plugging is the interchanging (by relays) of any two leads of a 3-phase motor to reverse the direction of rotation of the a-c field with respect to that of the rotor.

Motors up to 1 horsepower (hp) can usually be started or stopped by closing or opening a switch that connects the motor directly to the power source. To provide automatic protection against overload, fuses or circuit breakers are to be used. Circuit breakers may be incorporated in the design of the main switch. Motors rated from 1/20 to 1 hp, are sometimes furnished with the so-called sentinel breaker. The sentinel breaker is a small combination switch and circuit breaker containing a bimetallic thermal

Table 3-1.—Troubleshooting Chart for Power Circuit Breakers.

Trouble	Cause	Remedy
Overheating.	Poor condition of contacts:	
	1. Out of proper alignment and adjustment.	1. Contacts should be lined up and adjusted properly.
	2. Burned and pitted because of lack of attention after many heavy operations, or too frequent operation.	2. Burned and pitted contacts (other than silver) should be dressed up, if practical, or replaced with new parts. (High-pressure butt-type contacts usually do not require dressing. Silver-to-silver contacts are very rarely dressed.
	3. Breaker kept closed (or open) for too long a period (copper contacts).	3. Operate breaker more frequently to wipe contacts clean. It may be advisable to consider the installation of new silver-to-silver contacts. The manufacturer's nearest office should be consulted.
	4. Overloading (continuous of prolonged current in excess of breaker rating).	4. If the breaker is overheating because of excess current, one of two remedies can be followed: a. replace with breaker having adequate rating for the present or future load; b. arrange circuits so as to remove the excess load.
	5. Transmission of heat to the breakers from overheated or inadequate cables or connection bars.	5. If the bars or cables overheat because of current in excess of their capacity, this can be remedied by increasing the carrying capacity (that is, increasing the size or number of conductors) or by removing the excess current from the circuit.

Table 3-1.—Troubleshooting Chart for Power Circuit Breakers. (Continued)

Trouble	Cause	Remedy
Overheating (Cont'd).	6. Loose connections or terminal connectors.	6. Tighten.
	7. Ambient temperature too high.	7. Relocate in a cooler place, or arrange some means of cooling.
Failure to trip.	1. Mechanism binding or sticking. Caused by lack of lubrication or mechanism out of adjustment.	1. Lubricate mechanism. Adjust all mechanical devices, such as toggles, stops, buffers, and opening springs, according to instruction book.
	2. Failure of latching device.	2. Examine surface of latch. If worn or corroded, replace. Check latch wipe, and adjust according to instruction book.
	3. Damaged trip coil.	3. Replace damaged coil.
	4. Blown fuse in control circuit (where trip coils are potential type).	4. Replace blown fuse.
	5. Faulty connections (loose or broken wire) in trip circuit.	5. Repair faulty wiring. See that all binding screws are tight.
	6. Damaged or dirty contacts on tripping device.	6. Dress or replace damaged contacts or clean dirty contacts.
Failure to close or to latch closed.	1. Mechanism binding or sticking because of lack of lubrication or improper adjustment of breaker mechanism.	1. Lubricate mechanism. Adjust all mechanical devices, such as toggles, stops, buffers, and opening springs, to specifications in breaker instruction book.
	2. Burnout of operating (closing) coil (of electrically operated breakers) caused by operator holding control switch closed too long.	2. Replace damaged coil and teach operator how to operate properly. A better remedy would be to change the connections to include an auxiliary switch, which automatically cuts off the closing coil as soon as the breaker closes.

Table 3-1.—Troubleshooting Chart for Power Circuit Breakers. (Continued)

Trouble	Cause	Remedy
Failure to close or to latch closed (Cont'd)	3. Closing relay sticking.	3. Check or adjust closing relay.
	4. Cutoff switch operating too soon.	4. Adjust operation of cutoff switch to delay cutoff so as to allow breaker to close fully.
	5. Cutoff switch operating too late, causing the breaker to bounce open.	5. Readjust to reduce power at end of stroke and eliminate bounce.
	6. Insufficient control voltage (of electrically operated breaker) caused by:	6. (See a, b, c, below)
	a. Too much drop in leads.	a. Install larger wires; improve contact at connections.
	b. On a-c control--poor regulation.	b. Install larger control transformer. Check rectifier, and be sure it is delivering adequate d-c voltage from adequate a-c supply.
	c. On d-c control--battery not fully charged or in poor condition.	c. Give battery a sustaining charge, or repair according to instructions in battery manufacturer's manual.
	7. Blown fuse in control circuits, faulty connection or broken wire in control circuit, damaged or dirty contacts in control switch (electrically operated breaker).	7. Replace blown fuse; repair faulty connection or broken wire; dress or replace damaged contacts or clean dirty contacts in control switch.
Insufficient oil (in oil-circuit-breaker (tanks)	Leakage of oil. Oil throw during operation.	Locate point of leakage, and repair. Tighten joints in oil lines. Fill oil tanks to proper oil level. (Modern G-2 oil-blast breakers do not throw oil when interrupting current within their rating.)

Table 3-1.—Troubleshooting Chart for Power Circuit Breakers. (Continued)

Trouble	Cause	Remedy
Dirty oil (in oil-circuit-breaker tanks)	Carbonization from any operations	Drain poor oil and filter or replace with new oil. Clean inside of tank and all internal parts of breaker.
Moisture present in oil	1. Condensation of moist atmosphere. 2. Entrance of water from rain or other source.	1. Drain and filter oil or put in new oil. 2. Repair source of water entrance.
Sludging of oil	Overheating.	Filter or put in new oil. Remove source of overheating.
Gaskets leaking	Improper installation of gaskets at a previous inspection or repair. Oil saturation.	Put in new gaskets, treated in accordance with breaker instruction book.
Insulation failure	Absorption of moisture and accumulation of dirt, grime, carbon, and the like on bushing and insulating parts.	Thoroughly clean all insulated parts. Bake or dry out water-soaked parts (or treat in accordance with directions in breaker instruction book).

element. This thermal element will not trip immediately when an overload occurs; however, if there is a sustained heavy load the breaker will trip before the motor is damaged.

Some of the most common types of controllers used with a-c motors are:

Across-the-line starters

Primary resistance starters

Secondary resistance starters

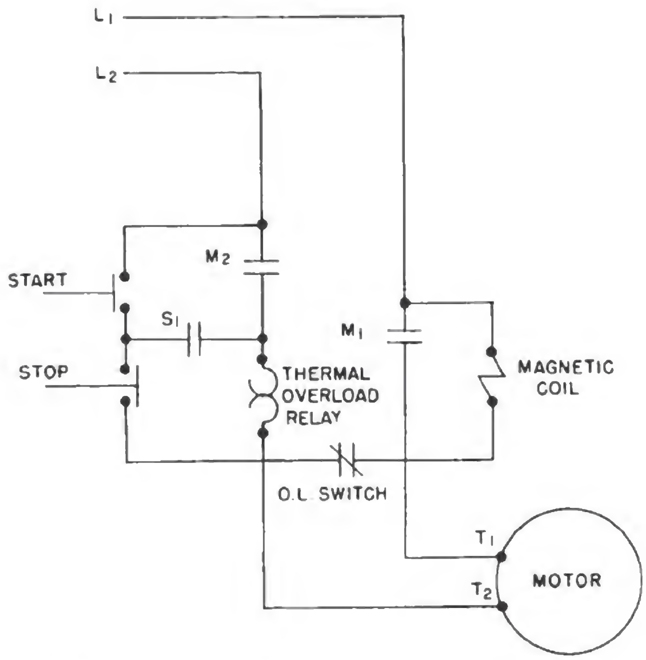
Autotransformer or compensator starter

Star delta starter

Regardless of the type of controller, all of them have overload protection devices, and most of them give low-voltage protection or low-voltage release protection. Many controllers are designed to withstand high mechanical shock and are equipped with manual latches or automatic latching relays to prevent false operation. Some typical controllers and wiring diagrams are shown in this chapter. A thorough knowledge of controller circuits and their operating characteristics will help you to install, maintain, and repair a-c controllers.

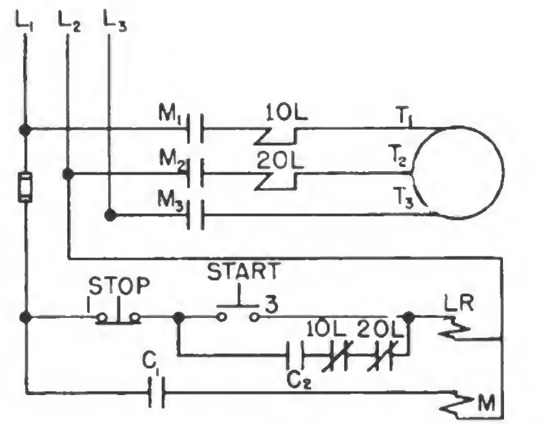
MAGNETIC ACROSS-THE-LINE STARTERS

A single-phase push button magnetic across-the-line starter connection is illustrated in figure 3-8. Both line leads are connected to the motor terminals through the main contacts M1 and M2, which close or open when the appropriate button is pushed. The thermal relay protecting the motor is connected in series with L2 in figure 3-8. A control circuit supplying the operating coil is connected across the main line.



26.14

Figure 3-8.—Line diagram of a single-phase magnetic across-the-line controller.



26.15

Figure 3-9.—Wiring diagram of a three-phase magnetic across-the-line starter with three-wire remote control.

(The light line in fig. 3-8 is the control circuit; the heavy line is the main circuit.)

The magnetic coil circuit can be opened either by pressing the STOP button, or by operation of the thermal overload relay. Both of these actions deenergize the magnetic coil and open contacts M1, M2 and S1.

When the START button is depressed, the control circuit is connected across the line. The electromagnet is energized and closes the main contacts M1, M2 which connect the motor across the line. The holding contact S1 is also closed by the electromagnet and remains closed after release of the START button to keep the magnet coil energized.

Illustrated in figure 3-9 is a line diagram of a 3-phase magnetic across-the-line starter. The 3-phase magnetic across-the-line controller operates on the same principle as the single-phase unit except there are three line leads connected to the motor; also notice in figure 3-9 that the motor protecting thermal overload relay heaters are in series with L1 and L2 to the motor. Normally only two thermal overload relays are required to adequately protect the 3-phase motor.

When the START button is depressed, a circuit is completed from L1 through the START and STOP buttons and the coil of latching relay (LR) to L2. The coil of LR is energized and LR operates to close relay contacts C1 and C2. This action completes a circuit through coil M. Coil M is energized and closes the main line contacts M1, M2, and M3; this action connects the motor directly across the line.

The latching relay contact C1 completes the circuit to the coil of the main line contactor. Contacts C1 and C2 are mechanically connected by a lever which prevents them from opening as a result of a shock. Also, when the latching relay opens, it operates a mechanical latch which prevents the main contactor from closing while it is electrically deenergized.

When the STOP button is depressed, the latching relay is deenergized and contacts C1 and C2 open. This de-energizes the coil of the main contactor and causes the main contacts to open.

You will notice that the overload relay contacts are in the control circuit, but are operated by heating elements placed in the main lines. The relays are reset by depressing the reset button. The control circuit is FUSED to protect the control circuit when remote control switches are used.

The starter also gives LOW-VOLTAGE PROTECTION by allowing the magnetic contactor to open when the line voltage fails or goes below a certain value. When the voltage is restored to its normal value, the motor will not start again until the START button is depressed.

PRIMARY RESISTOR CONTROLLER

Primary resistor starters are used on motors to reduce the sudden surge of current on starting, or when it is desirable to avoid sudden mechanical shock to the driven load. A typical line diagram of a magnetic primary resistor starter is illustrated in figure 3-10. Notice that the resistors are connected in the motor circuit.

The two-point magnetic type starter is suitable for most applications. The two-point type starter is generally made up of an accelerator control, an overload relay, a timing relay, starting resistors, and a line contactor.

In operation the line contactor (M) is first to make contact, energizing the motor through the starting resistors. Then the time relay is activated after a predetermined time interval, closing the accelerating contactor (A), and cutting out the starting resistance, thereby placing the motor directly across the line. The motor now runs at full speed because all resistance has been cut out.

SECONDARY RESISTOR CONTROLLER

The magnetic secondary resistor controller is used in conjunction with a wound rotor motor requiring automatic acceleration. This type of starter usually consists of primary contactors, starting duty resistors for the motor secondary, overload relays, and the required number of timed-accelerating contactors.

In operation, depressing the starter button closes the main line contactors, placing the rotor in series with the resistors, and the stator directly across the line. The contacts of the timed accelerator progressively short out the secondary resistance until the slip rings are short circuited, thereby bringing the motor up to full speed. A line diagram of the secondary resistor is shown in figure 3-11.

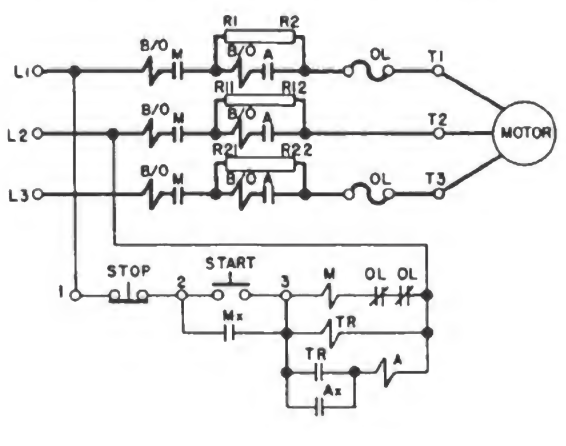


Figure 3-10.—Typical schematic diagram of a two-point primary resistor starter.

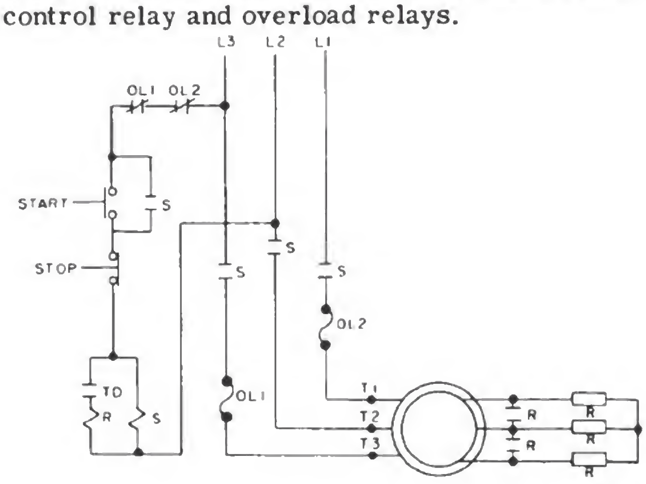


Figure 3-11.—A line diagram of a typical secondary resistor starter.

AUTOTRANSFORMER CONTROLLER

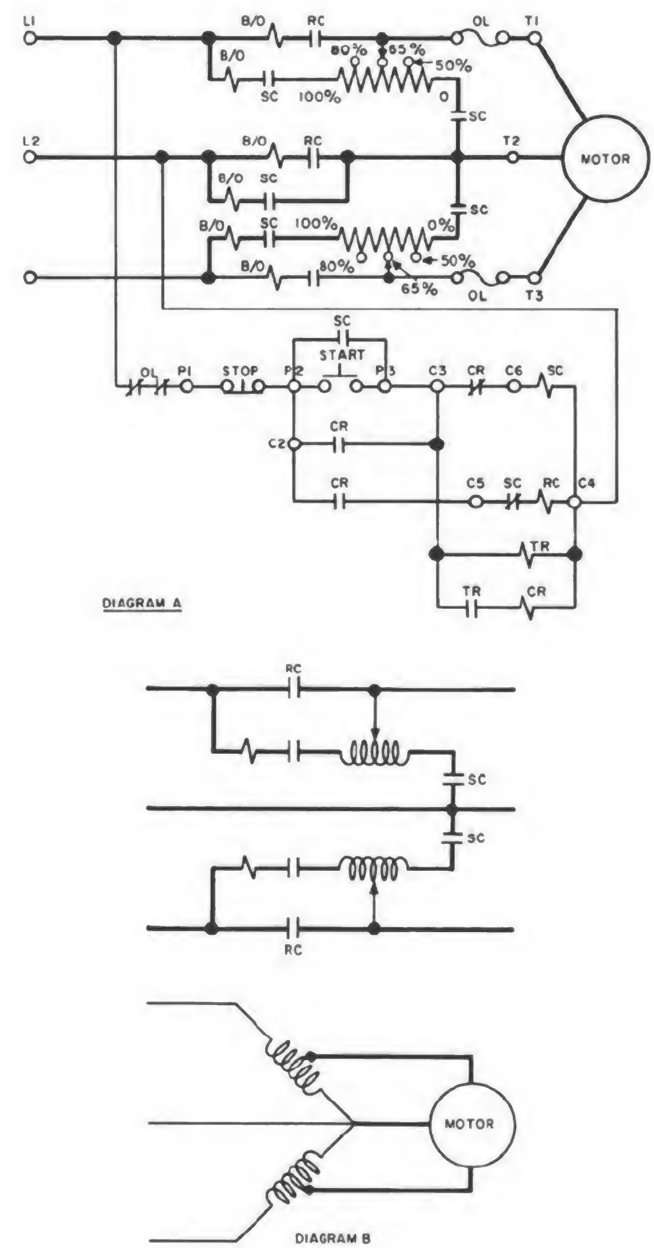
An autotransformer starter (fig. 3-12) reduces the voltage applied to the motor during the initial starting period. It is used advantageously where high starting line currents must be reduced (more than with resistor starters) or where the starting torque of the motor must be adjusted to meet the particular load requirement.

One advantage of the autotransformer starter is that the action of the transformer, rather than the resistance, reduces the voltage; therefore, no energy is lost through heat. A disadvantage of this type starter is a temporary, but complete loss of power on the motor terminal when the motor is disconnected from the transformer taps and transferred to the power line.

Figure 3-13A is a simplified schematic of an autotransformer having three laminated iron cores (one for each phase, star connected) wound with a coil or wire containing several taps to obtain a variation of voltages. The schematic (fig. 3-13A) indicates that each coil is connected at the center and connected to the 3-phase motor. This gives the motor only one-half of the line voltage at the start.

The control equipment in the schematic shown in figure 3-13B includes the START and RUN contactors, autotransformer, timer relay, control relay and overload relays.

26.18X
Figure 3-12.—Autotransformer starter.



26.19X
Figure 3-13.—A. Line diagram of an autotransformer starter.
B. Simplified schematics of the primary circuit.

In operation the start button if depressed energizes the START contactor (SC), which in closing connects the motor to the line by way of reduced voltage taps on the autotransformer, and simultaneously energizes the timing relay (TR). At the conclusion of the timing period, determined by the setting of the timer, the timer contacts (TR) close. Contacts (TR) in closing actuate the control relay (CR) which then functions to open the START contactor (SC) and energize the RUN contactor (RC). When the RUN contactor (RC) closes, the motor is connected directly across the line. Magnetic contactors (SC and RC) are cross-interlocked to prevent both units from closing. Simultaneous closing of these magnetic contactors would cause an over-voltage on the autotransformer.

Full line voltage is applied to the autotransformer primary. Starting current supplied at reduced voltage is higher than line current during this period. The usual time limit for bringing a loaded motor to two-thirds or more of its full speed is between 20 to 30 seconds.

STAR DELTA STARTING

The star delta starting method of reduced voltage can only be applied to motors having a delta connected winding that changes the motor terminal connection during the starting period. If the winding is changed from a delta connection to a star connection, the voltage across the windings is reduced to 57.7 percent of the line voltage. After the motor is started, the windings are reconnected delta, and the voltage across them is line voltage.

All the phase leads are brought out to the terminal box, so that the connection may be easily changed.

Figure 3-14 is a wiring diagram of a magnetic controller used for star delta starting. When the start button is depressed, contactor coil M is energized and closes contacts M1, M2, and M3, which connect phase leads T2, T4, and T6 across the line. At the same time, relay R and magnetic contactor S are energized. Contactor S closes S1, S2, and S3, which connect phase leads T1, T3, and T5 together. The motor winding is then star connected and connected across the line.

Relay R is a time relay. After a predetermined time delay, it opens the control circuit of contactors S and closes the control circuit of contactor D. Contactor S opens contacts S1, S2, and S3. Contactor D closes contacts D1, D2, and D3. Contacts D1, D2, and D3 connect T1, T3, and T5 to T6, T2 and T4 respectively and make a delta connection of the stator winding. Contacts M1, M2, and M3 remain closed so that the motor is connected across the line.

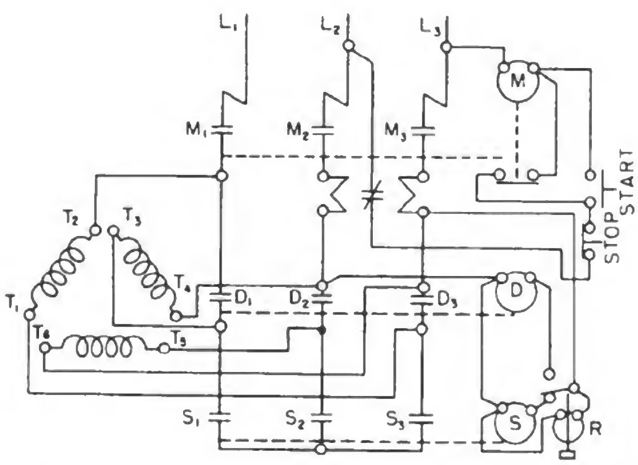


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Figure 3-14.—Wiring diagram for a star-delta magnetic controller.

Thermal cutouts and relays, and other devices for motor-running protection which are not capable of opening short circuits, must be protected by fuses or circuit breakers. The rating or setting of these protective devices must not be over four times the rating of the motor for which they are designed. The only exception is when they are approved for group installation, and are marked to indicate the maximum size of fuse by which they must be protected.

A motor-running protective device which can restart a motor automatically after overcurrent tripping must not be installed unless approved for use with the motor which it protects. A motor which can restart automatically after shutdown must not be installed so that its automatic restarting can result in injury to personnel.

Motor-running overcurrent devices other than fuses must have a rating of not less than 115 percent, nor more than 125 percent of the full-load current rating of the motor.

SAFETY CODE FOR MOTORS AND MOTOR PROTECTION

In installing motors or motor controllers various requirements are necessary for safety of personnel and equipment. Below are some of the requirements for motor markings:

A motor shall be provided with a nameplate showing the maker's name, the rating in volts and amperes, including those of the secondary if a wound rotor type of motor, the normal full-load speed and the interval during which it can operate at full load starting cold, before reaching its rated temperature. The time interval shall be 5, 15, 30, or 60 minutes, or continuous.

A motor rated at 1/8 horsepower or larger shall have the horsepower rating marked on the nameplate except that the motors of arc welders may be marked in amperes.

An alternating current motor rated at 1/2 horsepower or larger, unless it is a polyphase wound-rotor motor, shall have the nameplate marked with a code letter to show its input in kilovolt-amperes with locked rotor.

SOME REQUIREMENTS FOR MOTOR CONTROLS AND MOUNTINGS

Controllers must show the manufacturer's name or symbol (for instance, SQUARE D); the voltage rating or ratings; the horsepower capacity or current carrying capacity; any data

needed to indicate for what type of motor the controller is suitable; and terminal numbering (example, L1, L2, T1, and so on).

Control cabinets may not be used as a junction box, raceway, etc., for circuits containing apparatus other than the motor and controller connections.

Motors must be located so that: adequate ventilation is provided; maintenance such as lubrication of bearings and replacing of brushes can be readily accomplished; sparks from the commutator or collector rings will not cause fire hazards; and they are within sight of and not more than 50 feet from the controller.

The frames of stationary motors must be grounded. All motors must also be permanently and effectively grounded.

The preceding are but a few of the requirements for the installation of motors and their controls. If there is any doubt in your mind about the requirements for the installation of motors and their controls, or for almost any electrical requirements, you should consult the appropriate Navy or National electrical code or the appropriate Navy publication.

MAINTENANCE OF CONTROLLERS

The most important rule to remember when making repairs or inspecting motor controllers is — BE SURE THE CONTROLLER IS DISCONNECTED FROM THE POWER SOURCE BEFORE TOUCHING ANY OF THE OPERATING PARTS.

After the power source is disconnected, you can go ahead with your work. The first thing that should be done to keep controllers operating at maximum efficiency is to keep them free from dirt, dust, grease, and oil, both inside and out. Clean the operating mechanism and contacts with a clean, dry, lintless cloth, or with a vacuum cleaner. Small and delicate mechanical parts may be cleaned with a small, stiff bristle brush and a Navy approved solvent, NEVER USE CARBON TETRACHLORIDE.

If the manufacturer's instruction sheets for a device indicate bearing surfaces are to be lubricated, the bearing surfaces should receive a few drops of light oil, and all excess oil should be wiped off. In general, bearings which operate on a shaft or pin require lubrication. But knife edge bearings and plunger type armatures, which may become gummed up, SHOULD NOT BE OILED.

COPPER CONTACTS

Copper contacts are used for most heavy duty power circuits, and in many cases, in relay and interlock circuits. They should be inspected regularly. If projections extend beyond the contact surfaces, or if the contacts are pitted or coated with copper oxide, they should be dressed down with fine sandpaper.

Welding of contacts sometimes occurs. In spite of all precautions, low voltage is the most common cause. Welding may also result from overloads, low contact pressure resulting from wear or weak springs, loose connections, or excessive vibrations. If welding occurs, it is an indication of trouble in the electrical system. The contacts will have to be replaced, but it is useless to replace them unless the cause of the welding is found and corrected.

CARBON CONTACTS

Carbon contacts are used when a contactor is frequently opened and closed. It is essential that the contactor be open when it is deenergized. Since carbon contacts will not weld together when closed, they are better than metal contacts for ensuring that a deenergized contact is open. Carbon contacts are used only when necessary, however, because the current capacity of carbon per square inch of contact surface is very low; therefore the contacts made of carbon must be relatively large.

SILVER CONTACTS

Silver contacts are used extensively in pilot and control circuits, on relays, interlocks, master switches, and so on. They are used also on smaller controllers, and on heavy duty equipment where the contactors remain closed for long periods of time with infrequent operation. Silver contacts are used because they ensure better contact than other less expensive material.

Pure silver contacts and silver cadmium-oxide contacts should not be replaced until they become too worn to give good service. Their appearance will indicate when they are worn to such an extent that they are no longer serviceable. (See fig. 3-15.)

Normally, contacts are subjected to electrical and mechanical wear as they establish and

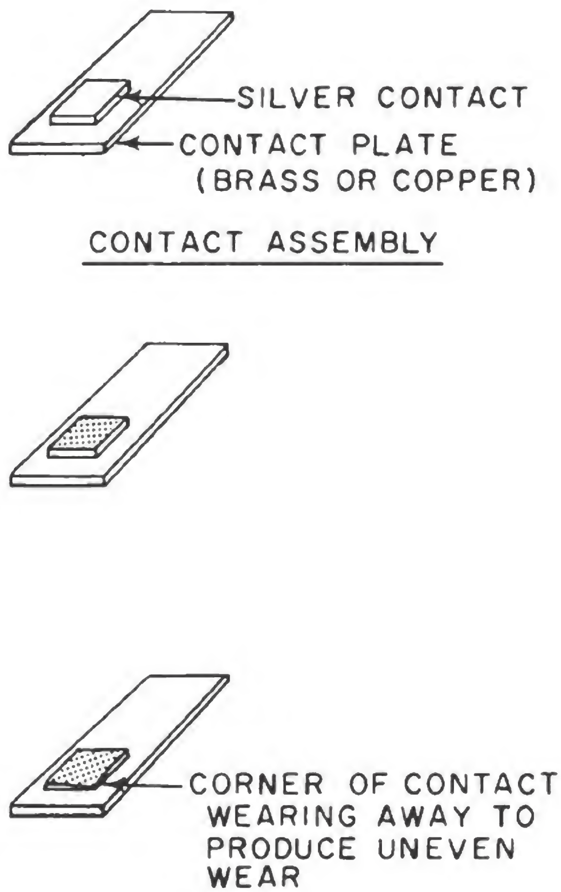

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Figure 3-15.—Silver contact.

interrupt electric currents. Electrical wear is usually greater than mechanical wear. If a movable contact assembly has no appreciable sliding action on its associated stationary contact assemblies, mechanical wear will be insignificant.

Electrical wear or erosion is caused by arcing when the contacts are establishing and interrupting currents. During arcing, a small part of each contact is melted, vaporized, and blown away from the contact.

As a pure silver contact erodes, its arcing surface changes in color, contour, and smoothness. Figure 3-15 shows typical changes in contour and smoothness. Normally, a new contact has a uniform silver color, a regular contour, and a smooth arcing surface. (Figure 3-15, top). As the contact wears, discolorations usually give it a mottled appearance, showing silver, blue, brown and black. The black color comes from the silver oxide formed during arcing. Silver oxide is beneficial to the operation of the contact. **Figure 3-15, center.**

Electrical erosion may cause uneven wear of the contacts and consequent contour-irregularity. Uneven contact wear does not necessarily indicate that the contact be replaced. To allow for uneven contact wear, manufacturers usually provide a total thickness of silver equal to twice the wear-allowance associated with the contact. **Figure 3-15, bottom.**

Melting and vaporization of contacts cause pitting of the arcing surface. The pitted surface has high spots which are quite small in area; tests indicate that such a surface is better than a surface which has not been subjected to arcing, because its circuit-making reliability is improved.

A silver-cadmium-oxide contact shows the same wear characteristics as a pure silver contact, except that small black granules may be evident on the arcing surface. These granules are cadmium oxide, a black material which is scattered throughout the mixture which has formed on the contacts. Silver oxide is formed during arcing, just as with a pure silver contact. The addition of cadmium oxide greatly improves contact operation because it minimizes the tendency of the contacts to weld together, retards heavy transfer of material from one contact to the other, and inhibits erosion.

A contact is serviceable as long as its wear-allowance and that of its associated contacts exceed minimum value specified by the manufacturer. (Usually the minimum value is in the order of 0.015 to 0.030 inch.) The wear-allowance of contacts is defined as the total thickness of contact material which may be worn away before the contact of two associated surfaces becomes inadequate to carry rated current.

In an electric-motor contactor, the wear-allowance of the power pole contacts is usually related to the closed position of the magnetic operator. The wear-allowance of the power-pole contacts of a magnetic contactor is the amount of silver that can be worn away without resulting in a failure of contacts to touch when the magnetic operator is at its closed position.

BLOWOUT COILS

Blowout coils seldom wear out or give trouble when used within their rating. However, if they are required to carry excessive currents, the

insulation becomes charred and fails, causing flash-overs and failure of the device.

Arc shields are constantly subjected to the intense heat of arcing and may eventually burn away, allowing the arc to short circuit to the metal blowout pole pieces. Therefore, arc shields should be inspected regularly and renewed before they burn through.

Arc barriers provide insulation between electrical circuits and must be replaced if broken or burned to a degree where short circuits are likely to occur.

The importance of having clean, tight electrical connections cannot be overemphasized. Where practical, it is a good idea and a common practice to solder electrical connections.

Excessive slam on closing, particularly on a-c magnet -operated devices, will eventually damage the laminated face of the magnet armature and may damage the shading coil.

Magnet coils should be kept dry. Wet coils should always be dried out before using. They may be dried by baking them in an oven at 230° to 257° Fahrenheit. The length of time in the oven depends on the size of the coil.

Table 3-2 is a troubleshooting chart for a-c controllers.

Table 3-2.—Troubleshooting Chart for A-C Controllers.

FAILURE TO CLOSE	
Probable Cause	Remedy
No power.	Check power source. Replace faulty fuses.
Low voltage.	Check power-supply voltage. Apply correct voltage. Check for low power factor.
Inadequate lead wires.	Install lead wires of proper size.
Loose connections.	Tighten all connections.
Open connections and broken wiring.	Locate opens and repair or replace wiring. Remove dirt from controller contacts.
Contacts affected by long idleness or high operating temperature.	Clean and adjust.
Contacts affected by chemical fumes or salty atmosphere.	Replace with oil-immersed contacts.
Inadequate contact pressure.	Replace contacts and adjust spring tension.
Open circuit breaker.	Check circuit wiring for possible fault.
Defective coil.	Replace with new coil.
Overload-relay contact latched open.	Operate hand- or electric-reset.
FAILURE TO OPEN	
Probable Cause	Remedy
Interlock does not open circuit.	Check control-circuit wiring for possible fault. Test and repair.
Holding circuit grounded.	Test and repair or replace grounded parts.
Misalignment of parts; contacts apparently held together by residual magnetism.	Realign and test for free movement by hand. Magnetic sticking rarely occurs unless caused by excessive mechanical friction or misalignment of moving parts. Wipe off pole faces to remove accumulation of oil.
Contacts welded together.	See CONTACTS WELDED TOGETHER section.

Table 3-2.—Troubleshooting Chart for A-C Controllers. (Continued)

SLUGGISH OPERATION

Probable Cause	Remedy
Spring tension too strong.	Adjust for proper spring tension.
Low voltage.	Check power-supply voltage. Apply correct voltage.
Operating in wrong position.	Remount in correct operating position.
Excessive friction.	Realign and test for free movement by hand. Clean pivots.
Rusty parts due to long periods of idleness.	Clean or renew rusty parts.
Sticky moving parts.	Wipe off all accumulations of oil and dirt. Bearings do not need lubrication.
Misalignment of parts.	Check for proper alignment. Realign to reduce friction and test for free movement by hand.

ERRATIC OPERATION

(Unwanted openings and closures and failure of overload protection)

Probable Cause	Remedy
Short circuits.	Test and repair or replace defective parts.
Grounds.	Test and repair or replace defective parts.
Sneak currents.	These are usually caused by intermittent grounds or short circuits in the machines or wiring circuit. Test and replace faulty parts or wiring.
Loose connections.	Tighten all connections. Eliminate any vibrations or rapid temperature changes that may occur in close proximity to the controller.

OVERHEATING OF COILS

Probable Cause	Remedy
Shorted coil.	Replace coil.
High ambient temperature or poor ventilation.	Relocate controller, use forced ventilation, or replace with suitable type controller.
High voltage.	Check for shorted control resistor. Check power-supply voltage. Apply correct voltage.
High current.	Check current rating of controller. Make check for high voltage above. If necessary, replace with suitable type controller.
Loose connections.	Tighten all connections. Check for undue vibrations in vicinity.

Table 3-2.—Troubleshooting Chart for A-C Controllers. (Continued)

Excessive collection of dirt and grime.	Clean but do not reoil parts. If covers do not fit tightly, realign and adjust fasteners.
High humidity, extremely dirty atmosphere, excessive condensation, and rapid temperature changes.	Use oil-immersed controller or dust-tight enclosures.
Operating on wrong frequency.	Replace with coil of proper frequency rating.
D-C instead of a-c coil.	Replace with a-c coil.
Too frequent operation.	Adjust to apply larger control.
Open armature gap.	Adjust spring tension. Eliminate excessive friction or remove any blocking in gap.

CONTACTS WELDED TOGETHER

Probable Cause	Remedy
Improper application.	Check load conditions and replace with a more suitable type controller.
Excessive temperature.	Smooth off contact surface to remove concentrated hot spots.
Excessive binding of contact tip upon closing.	Adjust spring pressure.
Contacts close without enough spring pressure.	Replace worn contacts. Adjust or replace weak springs. Check armature overtravel.
Sluggish operation.	See SLUGGISH OPERATION.
Rapid, momentary, touching of contacts without enough pressure.	Smooth contacts. Adjust weak springs. Where controller has "JOG" or "INCH" control button, operate this less rapidly.

OVERHEATING OF CONTACTS

Probable Cause	Remedy
Inadequate spring pressure.	Replace worn contacts. Adjust or replace weak springs.
Contacts overloaded.	Check load data with controller rating. Replace with correct size contactor.
Dirty contacts.	Clean and smooth contacts.
High humidity, extremely dirty atmosphere, excessive condensation, and rapid temperature changes.	See OVERHEATING OF COILS.
High ambient temperature or poor ventilation.	See OVERHEATING OF COILS.
Chronic arcing.	Adjust or replace arc chutes. If arcing persists, replace with a more suitable controller.
Rough contact surfaces.	Clean and smooth contacts. Check alignment.
Continuous vibration when contacts are closed.	Change or improve mounting of controller.

Table 3-2.—Troubleshooting Chart for A-C Controllers. (Continued)

Oxidation of contacts.	Keep clean, reduce excessive temperature, or use oil-immersed contacts.
ARCING AT CONTACTS	
Probable Cause	Remedy
Arc not confined to proper path.	Adjust or renew arc chutes. If arcing persists, replace with more suitable controller.
Inadequate spring pressure.	Replace worn contacts. Adjust or replace weak springs.
Slow in opening.	Remove excessive friction. Adjust spring tension. Renew weak springs. See SLUGGISH OPERATION.
Faulty blowout coil or connection.	Check and replace coil. Tighten connection.
Excessive inductance in load circuit.	Adjust load or replace with more suitable controller.
PITTING OR CORRODING OF CONTACTS	
Probable Cause	Remedy
Too little surface contact.	Clean contacts and adjust springs.
Service too severe.	Check load conditions and replace with more suitable controller.
Corrosive atmosphere.	Use airtight enclosure. In extreme cases, use oil-immersed contacts.
Continuous vibration when contacts are closed.	Change or improve mounting of controller.
Oxidation of contacts.	Keep clean, reduce excessive temperature, or use oil-immersed contacts.
NOISY OPERATION (Hum or Chatter)	
Probable Cause	Remedy
Poor fit at pole face.	Realign and adjust pole faces.
Broken or defective shading coil.	Replace coil.
Loose coil.	Check coil. If correct size, shim coil until tight.
Worn parts.	Replace with new parts.
VIBRATION AFTER REPAIRS	
Probable Cause	Remedy
Misalignment of parts.	Realign parts and test for free movement by hand.
Loose mounting.	Tighten mounting bolts.
Incorrect coil.	Replace with proper coil.
Too much play in moving parts.	Shim parts for proper tightness and clearance.

VOLTAGE REGULATORS (FEEDERS)

Uniform voltage on feeder circuits is maintained by automatically operated voltage regulators that raise or lower the circuit voltage as load demands change. The voltage regulators discussed in this chapter are the single-phase station type induction and step voltage regulators that are used on primary distribution feeders. Although the details of construction of these regulators are different, their operating and control devices are similar.

INDUCTION REGULATOR

The induction voltage regulator consists of a fixed (secondary) and movable (primary) winding which rotates through 180° only. A motor and brake with a contact making voltmeter, line-drop compensator, and controls provide either automatic or manual operation. The regulator is normally designed for plus or minus 10 percent variation of the primary distribution voltage. The secondary winding is arranged in two coils which may be connected in series or in parallel, making possible the reconnection of a 10 percent regulator to provide only 5 percent regulation having double the current capacity. Figure 3-16 shows a cross section of an induction regulator. Figures 3-17 and 3-18 are line diagrams of an induction regulator compensator.

Figure 3-18 is a simplified schematic diagram of an automatically controlled induction regulator. Normally, the operation is as follows: When the voltage of the feeder is normal, the plunger of the voltage relay is in the middle position; the motor line switch is open; and the induction regulator is neither bucking nor boosting the voltage. When the feeder voltage drops, the plunger in the relay drops. This closes the switch in the motor circuit and causes the motor to rotate in the direction which will boost the voltage. The motor rotates until the voltage is raised to a point which will lift the relay plunger to its medium position. Should the voltage be increased above normal, the relay plunger would go above the medium position, thereby closing a contact above. Closing this contact forces the motor switch to close in the opposite direction, thereby reversing the rotation of the motor. This will now cause the regulator to buck the voltage and lower it back to normal value. In all cases, the shunt winding is rotated until the voltage is brought to its normal value.

STEP VOLTAGE REGULATOR

The step voltage regulator provides economical and reliable regulation. This type consists essentially of a core and coil assembly, switching mechanism, motor, and control for both manual and automatic operation. Ordinarily all moving parts are accessible for inspection; this aids materially in reducing maintenance cost. Procedures for adjustments and normal maintenance usually are covered adequately in the manufacturer's instruction book provided with the equipment. Figure 3-19 shows a cutaway view of a step voltage regulator.

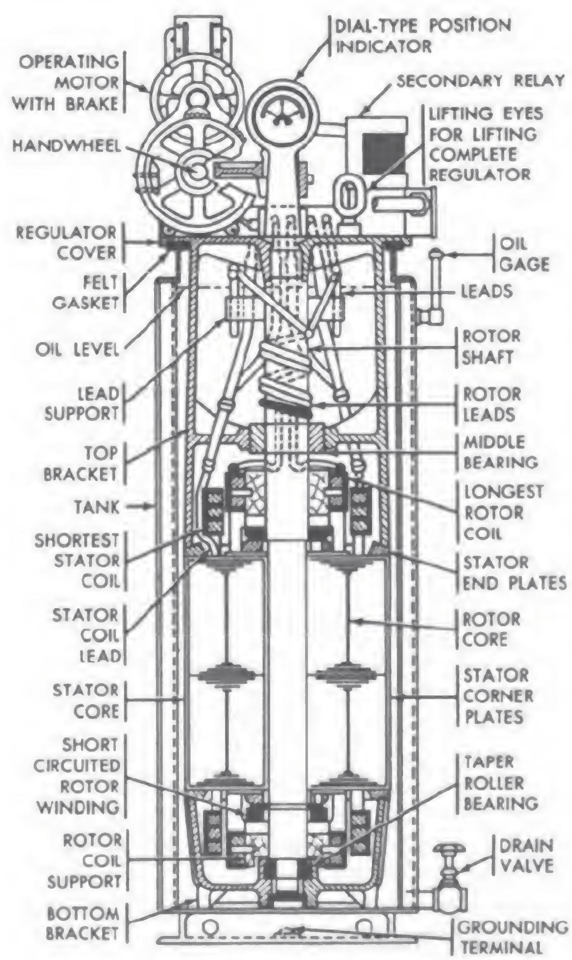

Figure 3-16.—Cross section of an induction regulator.

Figure 3-20 is a simplified wiring diagram of an automatically controlled step voltage regulator. The diagram is a 3-phase composite transformer with delta connected primaries and Y connected secondaries. Inserted in each phase wire is a series boosting transformer, the primaries of which are supplied through preventive coils and the tapped Y connected secondaries. The "tap changers" are motor driven and are immersed in oil.

In actual application you can use two single-phase regulators to regulate a 3-phase, 3-wire circuit adequately. Three single-phase regulators are required for a 3-phase, 4-wire circuit.

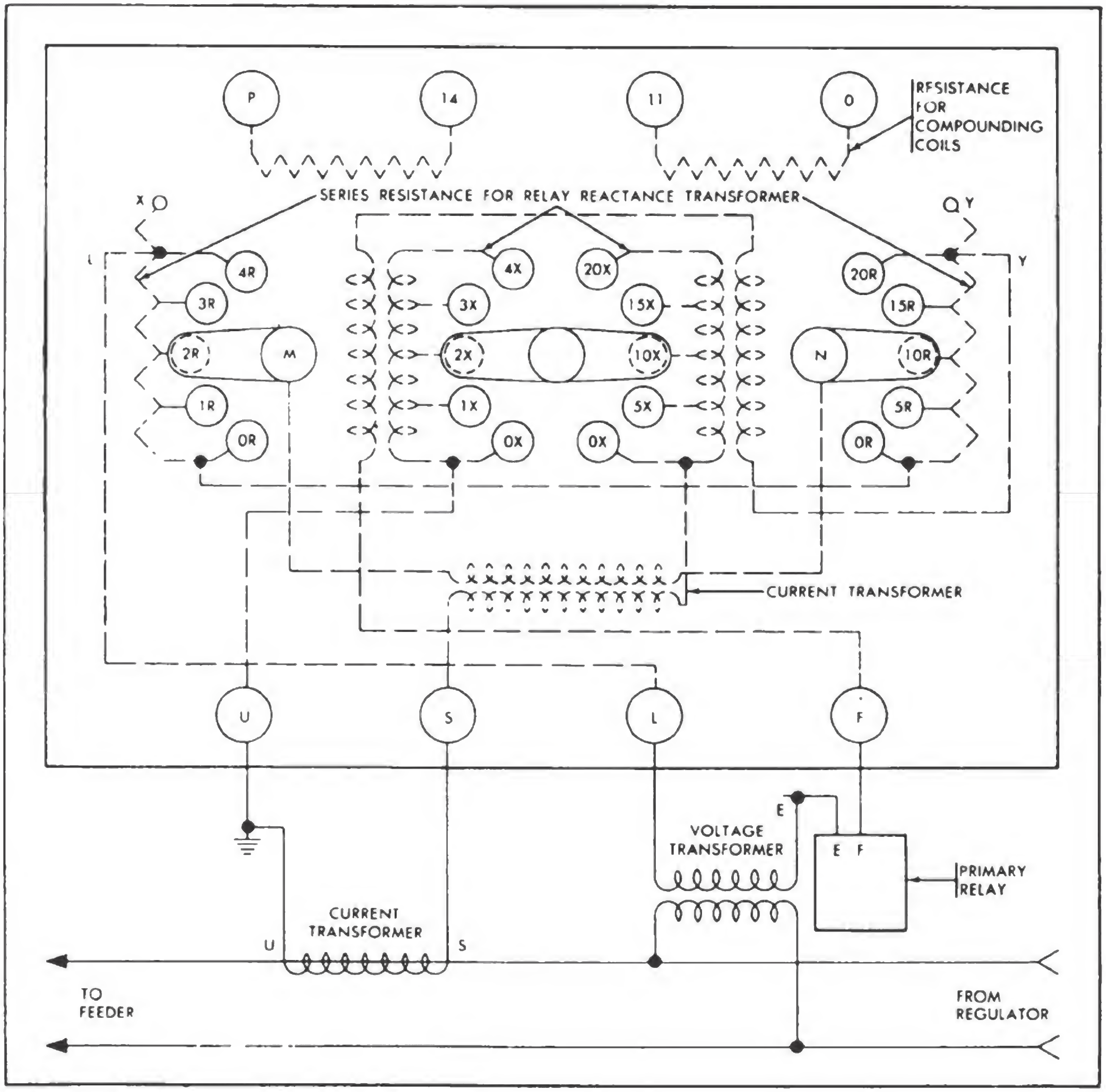

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Figure 3-17.—One type of induction regulator compensator.

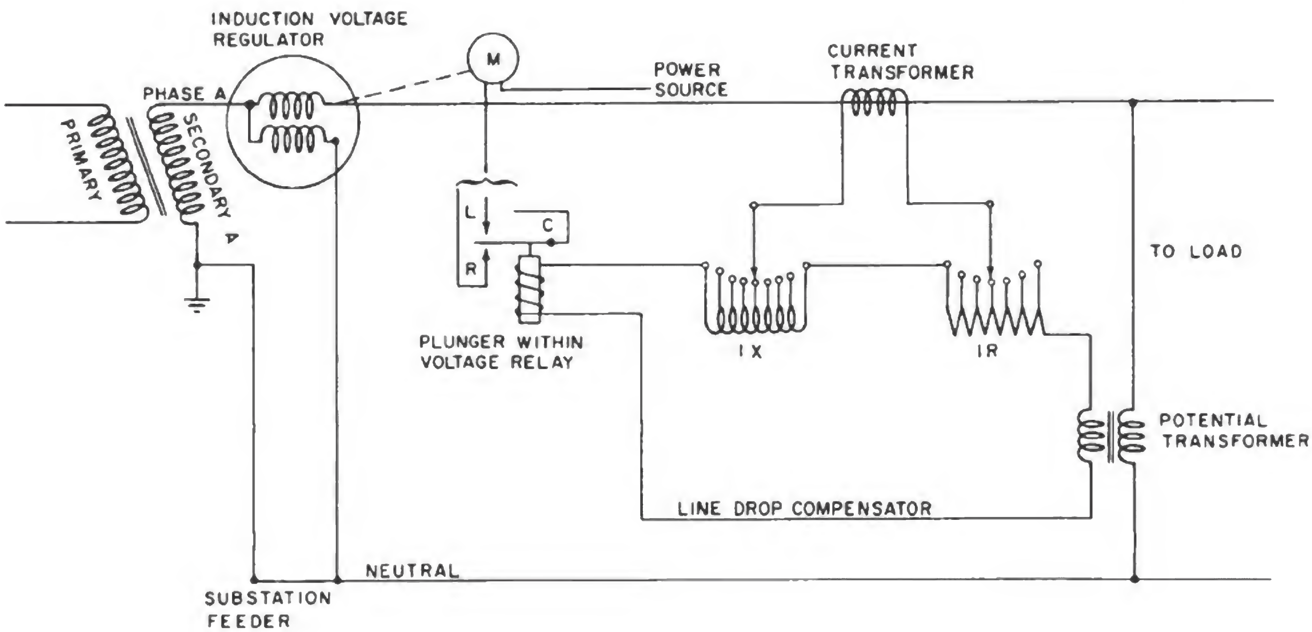

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Figure 3-18.—Schematic wiring diagram of an automatically controlled induction regulator.

Operation

Preliminary regulator adjustments for automatic operation are usually made from voltmeter readings at the load center during peak and off peak periods. A field man communicates the reading to the station operator who adjusts the regulator to deliver the desired voltage.

To maintain a reasonably constant voltage on the circuit, a measurement of the voltage at the load center must be obtained. If the regulators to be tested are in service and the contact making voltmeter and taps on the line-drop compensator (shown on fig. 3-18, but not on fig. 3-19) have been temporarily adjusted, the following procedure applies:

1. Choose a location at or near the load center of the circuit for obtaining voltage measurement records.
2. If lightly loaded transformers are available, they can generally be used with satisfactory results. If not, suitable potential transformers are connected across the phases to be tested. On 3-phase circuits, two of the phases should be tested simultaneously.
3. Install recording voltmeters at the secondary terminals of the transformers. These voltmeters should be tested and adjusted for accuracy before installation.
4. Leave the voltmeter in service for at least 24 hours. Remove the charts and reset the chart to be left on the voltmeters for further tests if required.
5. Study removed charts. If voltage is correct throughout the test period, make no further regulator adjustments. If voltage is uniformly too low or too high throughout the period, assume the line-drop compensator adjustment to be correct, but make further adjustments of contact making voltmeters. If voltage is too high or too low during heavy or peak load periods, but is correct during normal or light periods, assume the contact-making voltmeters adjustment to be correct, but make further adjustments of the line-drop compensator. For overvoltage, change taps to decrease compensation; for undervoltage, change taps to increase compensation. Frequently, voltage conditions require further adjustment on both contact making voltmeters and line-drop compensators. Most line-drop compensators have 24 1-volt steps across the resistance portion, and 24 1-volt steps across the reactance portion of the compensator. The numbers on the contacts indicate the volts of compensation obtainable. For figure 3-17, for example, with the arms on 2R, 2X, 10X and 10R, 12 volts (2+10) resistance and 12 volts (2+10) reactance compensation are obtained when the

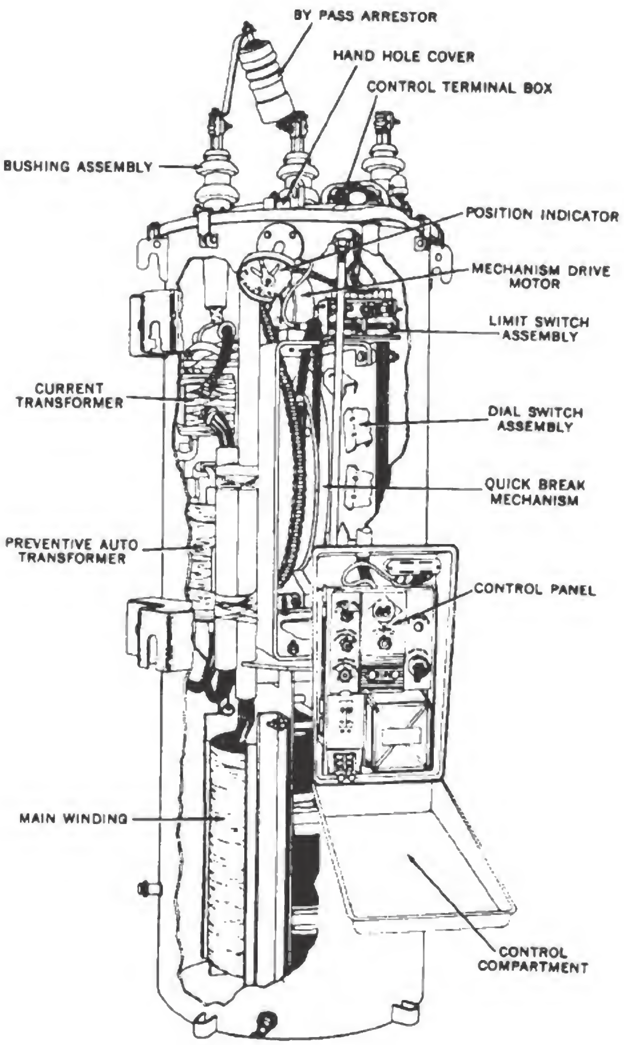

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Figure 3-19.—Cutaway view of a step voltage regulator.

rated full-load current is flowing in the secondary winding S U.

6. As a guide in determining proportionate volts resistance and volts reactance compensation needed, refer to resistance and reactance tables found in most electrical engineering handbooks. For example, on a 1/0 copper conductor circuit having an equivalent distance of 18 inches between conductors, a selected table from an electrical engineering handbook shows resistance in ohms per 1,000 ft to be 0.1002, and the reactance to the neutral in ohms per 1,000 ft

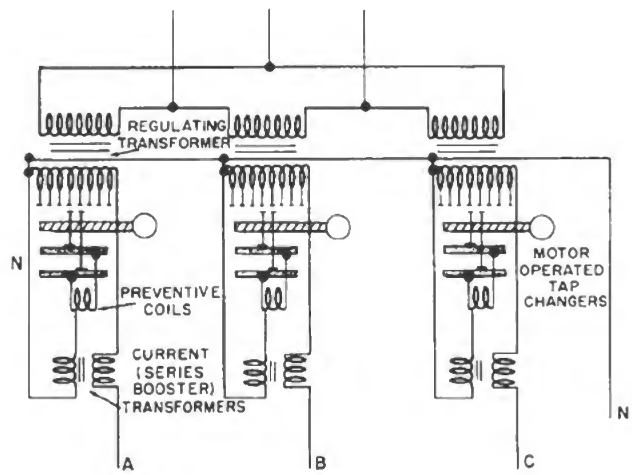

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Figure 3-20.—Schematic view of a step voltage regulator.

of one conductor of single or 3-phase circuit to be 0.1126 (ratio of 0.1002R to 0.1126X). Therefore, the circuit as indicated would need slightly more reactance compensation than resistance compensation. NOTE: For single-phase regulators on 3-phase circuits, adjustments may vary for each regulator because of unbalanced load conditions, variations in conductor spacing, and other variables.

7. After the charts have been studied and initial adjustments have been completed, leave the voltmeters in service for another 24-hour period. Study the charts for this second period and make further adjustments of regulator devices if necessary.

8. Continue the procedure as outlined until a reasonably constant voltage at the load center is maintained. One or two adjustments usually give satisfactory results. Ordinarily, a range within plus and minus 10 percent is acceptable.

9. For removing or replacing regulators and connections for single-phase regulators in various combinations and circuits, refer to applicable manufacturers' drawings.

Putting Regulator Into Service

Most regulator installations are provided with isolating and bypassing disconnecting

switches. The following procedure should be followed to place a regulator into service:

1. Check the nameplate data against the requirements of voltage and current. If the secondary has double current rating, connect the coils in series or multiple according to the capacity required. Tag the line and load sides of the regulator and operating motor for correct phase rotation.

2. To deenergize the feeder, open the circuit breaker at the switchboard controlling the feeder and regulator. Open the regulator isolating disconnects. If service must be maintained, close the bypassing disconnect and then close the circuit breaker at the switchboard. Position the regulator properly to accommodate incoming and outgoing connections without crossovers, and make the grounding connection first.

3. Make certain that the case is grounded through a heavy copper connection to the ground bus. The surface at the grounding point on the regulator should be clean, and a positive connection should be made.

4. For connections at regulators, refer to the diagram furnished with the apparatus. The corresponding primary and secondary coils must be connected to the same phase wires in the proper direction; otherwise, maximum regulation will not be secured, or the regulator will not function properly. Incorrect current direction will increase losses and heating. When the regulator under load is turned from either full buck or boost to neutral, the primary current should decrease. If it increases, reverse the line and load conductors of the regulator.

5. After the regulator is installed, make a thorough check of the connections. Then the isolating disconnects may be closed and the bypassing disconnect opened.

Cutting Regulator Out of Service

The following is recommended procedure for cutting regulator out of service:

1. Deenergize the feeder as described in the previous section, and isolate the regulator completely. If service on the feeder must be continued, close the bypassing disconnecting switch and close the feeder circuit breaker at the switchboard.

2. To disconnect the regulator, cut or open all circuit leads to the regulator, tagging them according to line and load sides. If necessary, trace the conductors back to the bus or other point, making positive identification.

Maintenance

Instructions contained in this paragraph apply in general to induction regulators. Complete maintenance procedures are covered in manufacturers' publications and should be followed in each instance.

When work is done near a regulator on a live circuit, extreme care shall be used in guarding against certain hazards. Frequently, cables from the regulators are unprotected except for the cable insulation, which may be insufficient to protect a person in direct contact with it. If lubrication is necessary, the automatic control should be opened and tagged to prevent operation.

Newer regulators have accessible oil cups and standard fittings to facilitate lubrication. Some outdoor regulators have a lamp placed in the top covering near the operating motor. This lamp is kept lighted during cold weather to prevent the oil in the motor bearings from congealing. In more modern equipment, strip heaters are installed to accomplish the same purpose and to maintain a dry atmosphere within the inclosure. Although the transformer oil in a regulator ordinarily does not need much attention, occasional inspection must be made for signs of leaks about the casing. The oil level should be checked regularly, either through a gage glass or through a hole in the inclosure. The oil must never be allowed to get below the bottom of the gage glass or below the tops of the windings. The following schedule for oiling is suggested:

1. Lubricate the top bearings every month by oiling the felt ring around the shaft in the recess at the top.

2. Lubricate the gear segment and worm with heavy grease every 6 months.

3. Keep the oilcups on motor bearings and wormshaft bearings filled. A good grade of ball-bearing grease should be used for motors having greased ball bearings.

4. Keep the grease cups filled on the rotary magnetic brake release (if used).

5. Place a drop of oil occasionally on the wearing points of other types of electrical brake-release mechanisms.

6. Be sure that the correct amount of oil is used. Any excess may be thrown on the brakeshoe, reducing brake effectiveness and causing the regulator to overrun.

Troubleshooting

The following points require attention, either at times of regular inspection or when locating causes of trouble:

If the regulator stalls or is sluggish in its operation, make the following checks and adjust if necessary:

1. Worm or sector gears may have changed their positions on the shaft. Correct by readjustment of gears.
2. Either the top or bottom bearing of the rotor shaft may be too tight. Dismantle the regulator for inspection and correction of the trouble.
3. Foreign matter may have become jammed in the gears.
4. The brake release may be inoperative, allowing the brake to drag continuously.

If a fuse is blown and a 220-volt supply switch is in the circuit, open it and replace the fuse; after that, close the switches again. If the wiring to any one motor is short circuited, open the automatic control switch for that motor circuit and leave it open when trouble is detected. The fuses may be blown by the combined starting currents of a number of motors at periods of rapid load changing or voltage disturbance on the bus.

Every 6 months the position indicator should be checked as follows:

1. Check all connections.
2. Check the indicator for accuracy if it is used for setting the regulator position when paralleling circuits.
3. Check signal lights (if provided) for maximum buck and maximum boost indication.
4. Check for automatic return to neutral position.

Heating may be detected by feeling the temperature of the drive motor casing, particularily during periods of rapid load changing. Failure of the circuit voltmeter to hold at the correct value may indicate a stalled motor. Humming of the motor without proper speed of rotation may be caused by single-phase condition. In the case of old regulators, check the limit switch to see if one contact opens before the other.

1. In some cases, the motor may move in jumps because of impulses of current when the relay switch makes contact; but it may move by jumps or inch along to the extreme position in the wrong direction, failing to clear on the limit switch.
2. If the motor overheats or acts sluggish, open the automatic control switch to prevent damage. Rotate the regulator by hand to detect mechanical trouble such as tight bearings, dry bearings, worm and sector gears binding, rotor binding or jammed against the limit stop, brake not releasing or too tight, or congealed oil in regulator motors outdoors. Low voltage or a single-phase condition of the supply circuit may cause sluggish action.

CAUTION: Before rotating the regulator by hand, open the automatic control switch to prevent personal injury that might result from the effort of the automatic controls to readjust voltage after changing voltage by hand operation. Any oiling or adjustment of the motor or gearing should be done only after automatic control has been removed.

CHAPTER 4
TESTING EQUIPMENT

After electrical generating plants, distribution systems, communications systems, and other electrical apparatus and equipment have been constructed and put into operation, they must be tested, inspected, and maintained.

In order to test, inspect and maintain electrical systems and equipment, you must know the principle and operating procedures of the various testing and measuring devices. These devices are used to test for grounds, opens, shorts, and to measure current, voltage, power resistance, frequency, etc.

The purpose of these devices is to test and measure accurately certain circuit values or to determine the operating condition of the electrical circuits. The accuracy of these instruments will depend on the type, sensitivity, useful range, and how they are treated.

POWER TEST EQUIPMENT

Four of the most commonly used electrical testing devices are the ohmmeter, voltmeter, ammeter, and the wattmeter. As you know, the ohmmeter measures the amount of resistance (ohms); voltmeter measures the amount of voltage (volts); the ammeter measures the amount of current flowing through a conductor (amperes); the wattmeter measures the amount of power being drawn by a piece of electrical device or apparatus (watts).

The principles and theories of the various types of testing and measuring devices are explained in Basic Electricity, NavPers 10086-A and Construction Electrician 3 & 2, NavPers 10636-D; therefore, they will not be repeated in this text.

DUCTER OHMMETER

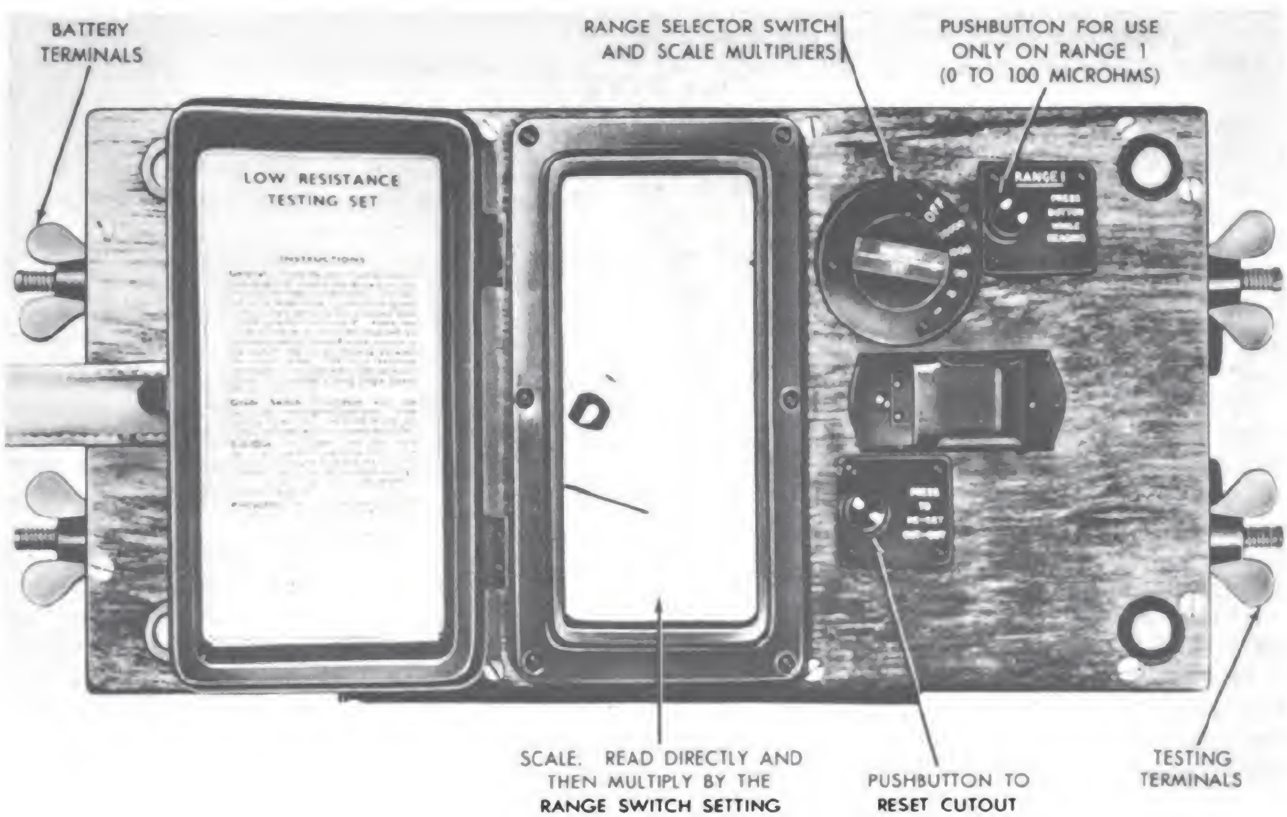
The ducter ohmmeter (fig. 4-1) is a device that is primarily used to measure very low resistances (0 to 1 ohm) of bus and circuit breaker contacts. It is used to measure connection and contact resistances. It is a direct-reading ohmmeter of rugged construction powered by its own source of low-voltage direct current. For convenience, this source of current can be three dry cells in parallel, except in the lowest ranges when a storage battery cell should be used. The ohmmeter is constructed in such a way that its reading is independent of the applied voltage.

The source of potential is connected so that the current flows through the instrument in series with the circuit to be measured, and the voltage leads of the instrument are connected across the portion of the circuit to be measured (fig. 4-2). The ducter is strictly a field instrument, being accurate only to about 1 percent. It is convenient to use because no current-regulating devices are necessary, the current being whatever the circuit resistance will pass.

In using the ducter ohmmeter to test an oil circuit breaker, the breaker is deenergized and isolated by disconnect switches. The breaker is closed by manual control. A test made for foreign voltages (to assure that the breaker is deenergized), should be followed by application of standard safety grounding. The ducter leads are then placed across the two risers of any one phase, preferably above the top connections to the bushings, as shown in figure 4-3. Readings are obtained similarly for the other two phases.

The following defects, not readily ascertained during overhaul, are typical of conditions that may be disclosed by the use of a ducter ohmmeter:

1. Loose connections at tops of bushings
2. Loose connection between central bushing study and bushing cap
3. Loose sweated lugs and poor connections under taped joints
4. Loose stationary contacts inside explosion chambers and grids
5. Loose arcing contacts
6. Oxidized contact surfaces
7. Cracked bayonet clamps



26.26

Figure 4-1.—Ducter ohmmeter (low resistance).

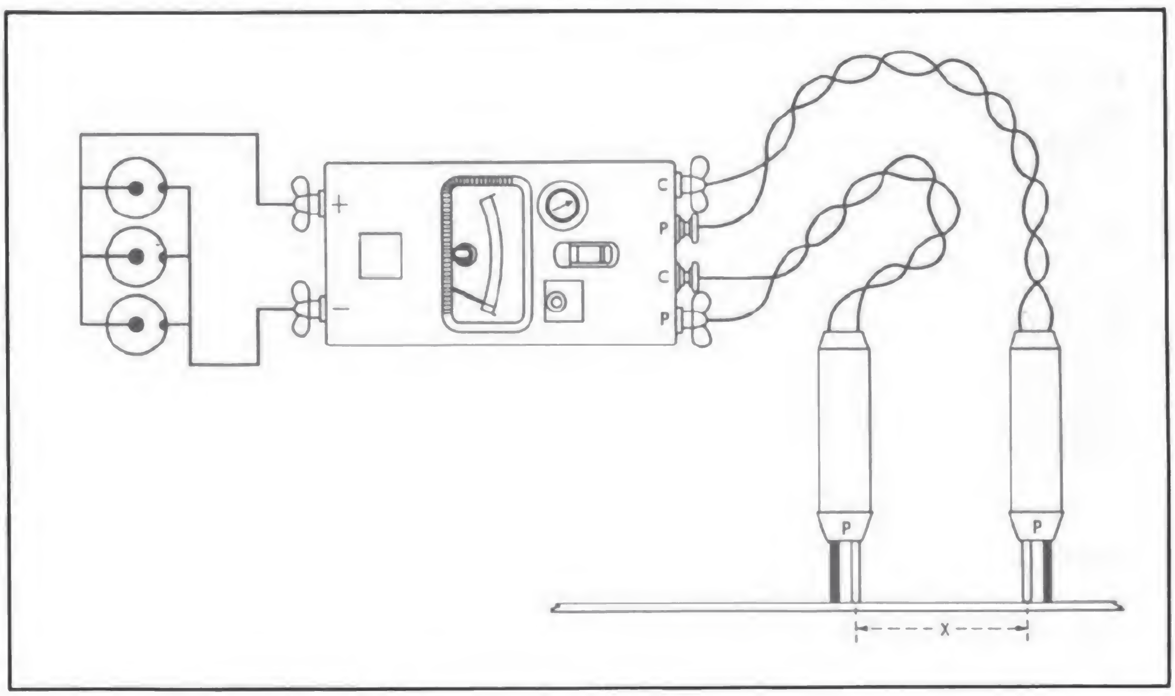
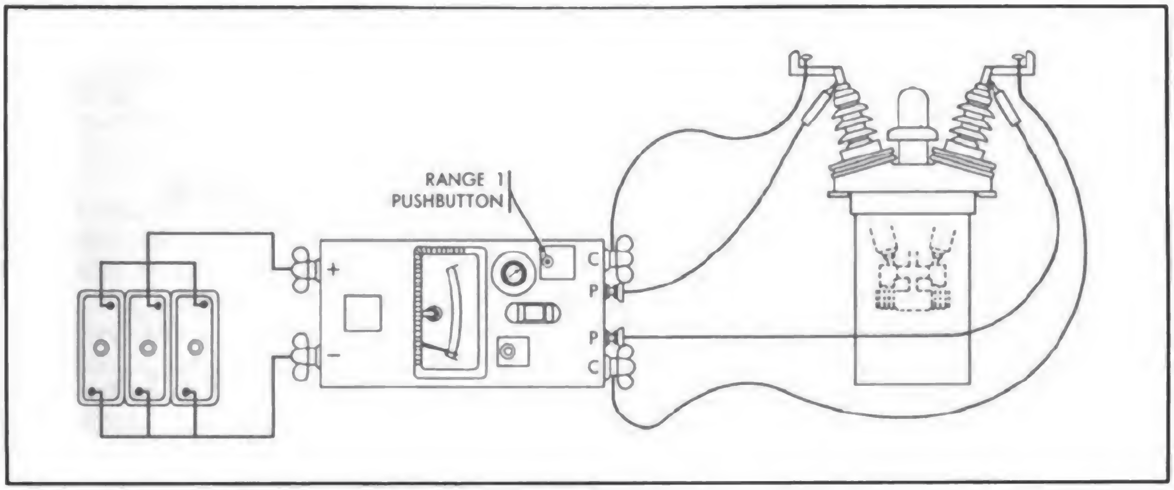


Figure 4-2.—Ducter testing with duplex helical handspikes.

26.27



26.28

Figure 4-3.—Ducter testing the contacts of a large circuit breaker.

8. Loose connections inside high-voltage current transformers
9. High-resistance connections on apparatus

Ducter ohmmeter tests should be made at least every 2 years in conjunction with power-factor tests. When testing low-voltage breakers (15-kv and lower) and readings exceed 5000 to 10,000 microhms, the cause of the high readings should be investigated and corrected.

MEGOHMMETER (MEGGER)

The megger is a high-range, direct-reading ohmmeter for measuring insulation resistance. It is primarily used for detecting and diagnosing insulation weakness in electric equipment and conductors.

The general procedure for testing substation transformers with a megger is as follows:

1. Open the oil circuit breakers to deenergize the transformer.
2. Open the disconnect switches on both sides of the transformer or transformer bank.
3. Check both sides of each transformer with a voltage detector.
4. Apply ground sticks or ground cables to terminals on both sides of the transformer bank.

CAUTION: Always connect one end of the grounding cable to ground first, then apply the other end of the grounding cable to the bus or metallic terminals of transformers.

5. Place switching tags on open switches.
6. Remove ground sticks to make insulation-resistance test.
7. Test the high-voltage and low-voltage windings separately to ground, connecting the line terminals of the windings and the ground terminal of the instrument to the transformer case.
8. Test between the high-voltage and the low-voltage windings.

The test outlined above is an overall test and includes the transformer bushings and other equipment such as bus support insulators. If insulation-resistance values are 2000 megohms or higher, no further tests are needed. If the values are below requirements, external leads should be disconnected and the insulation-resistance test repeated. If the second test shows resistance values as being still too low, oil samples should be taken to determine whether or not the low values may be due to deterioration of the oil. If this fails to locate the source or cause of low resistance values, there is no alternative except to remove the bushings and test the insulation of the coils and oil as a single homogeneous component. If the resistance is still too low, then the oil must be drained off and the source of trouble must be sought in the individual coils.

In testing transformers with a megger, the test should be made during clear, dry weather. The temperature and relative humidity of the air and general atmospheric conditions should be recorded at the time tests are being

made, if known. Test records should be kept as they show when trouble is developing as a result of gradual or sudden deterioration of the insulation or because of local leakage. For example, a 40-megohm reading on the primary winding of a 24,000/2400-volt transformer that has been testing about 500 megohms indicates trouble that should be remedied.

POWER CIRCUIT ANALYZER

Power circuit analyzer or industrial analyzer (fig. 4-4) is designed for alternating current only and should not be used on direct current.

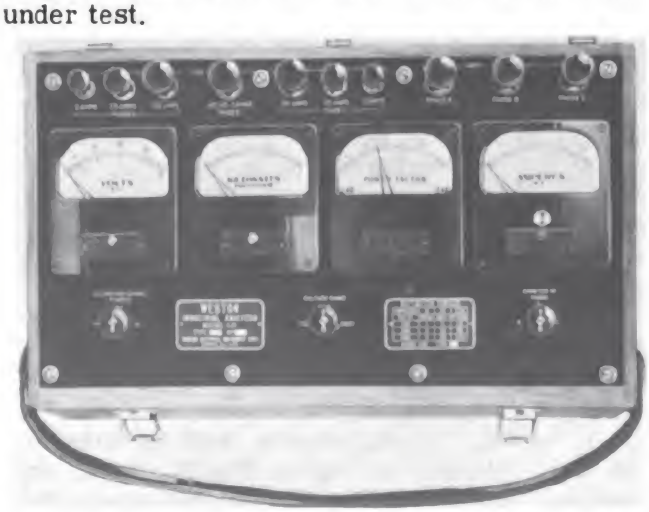
The analyzer consists of a voltmeter, ammeter, wattmeter, and a power factor meter (fig. 4-5), together with two current transformers and the necessary switches to facilitate the testing of three phase, three wire loads.

Although the analyzer has been designed primarily for three phase, three wire loads it can be used for measurements on single phase and other polyphase circuits.

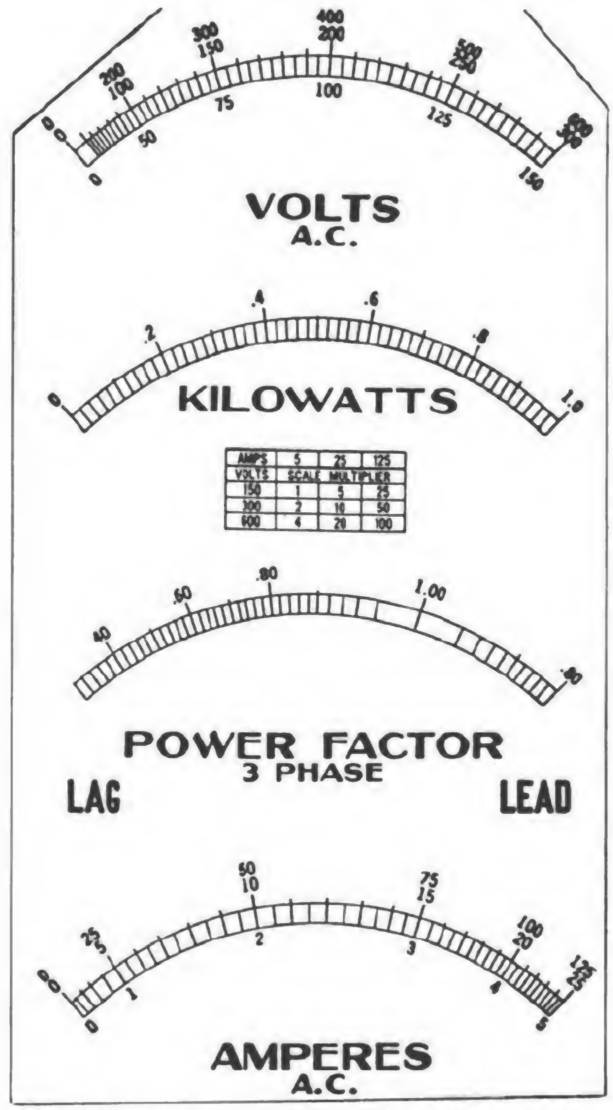
Before connecting the analyzer, it is advisable to set the voltage range changing switch to the 600 volt range unless the voltage to be measured is definitely known to be suitable for a lower range.

When testing other than a balanced 3 phase 3 wire load the indications of the power factor meter should be disregarded.

The VOLTMETER is of the movable iron type having its series resistance divided with a part connected to each side of the line under test.



26.29
Figure 4-4.—A-C power circuit analyzer.



DIMENSIONS..........................18 7/8X10 7/8X6 7/8
APPROXIMATE WEIGHT...........32 LBS.
ACTUAL SCALE LENGTH.........3½

26.30
Figure 4-5.—Scales of the power circuit analyzer.

Its indications are correct to ±1 percent of the full scale on any range, at any temperature between 20° and 40° C on any frequency from 25 to 125 cycles per second and on ordinary commercial wave forms.

The WATTMETER is of the electrodynamometer type, having two elements, designed for polyphase or single phase measurements.

The indications of the wattmeter, together with the transformers contained in the analyzer, are correct to ±2 percent of the full scale value on any range, at any temperature between 0° and

50° C on any frequency from 25 to 125 cycles per second and on ordinary commercial wave forms.

Multiplying (resistance) factors for the scale reading, depending on the current and potential ranges used, are to be found on the wattmeter scale.

The POWER FACTOR METER is of the crossed coil electrodynamometer type designed for balanced three phase three wire loads.

Its indications are correct to .01 PF when connected to a three phase three wire balanced load so that the phase rotation is A-B-C, at any temperature between 0° and 50° C at any frequency from 25 to 125 cycles per second, and on ordinary commercial wave forms. This same accuracy is maintained when the current is within 20 to 125 percent of the normal rating; that is, 1 to 6.25 amperes on the low range, 5 to 31 amperes on the medium range, and 25 to 156 amperes on the high range.

As mentioned previously, when the analyzer is connected to a single phase, two phase, or three phase four wire load the indications of the power factor meter should be disregarded.

The AMMETER is of the movable iron vane type designed for use with the current transformers contained in the analyzer.

The indications of the ammeter, together with the transformer contained in the analyzer, are correct within ±1 percent of the full scale value at any temperature 10° and 40° C at any frequency from 25 to 125 cycles per second and on ordinary commercial wave forms.

Independent of the transformers, the ammeter has a full scale range of 1 ampere. The scale is expanded in the center and contracted at each end. This characteristic is useful for motor testing.

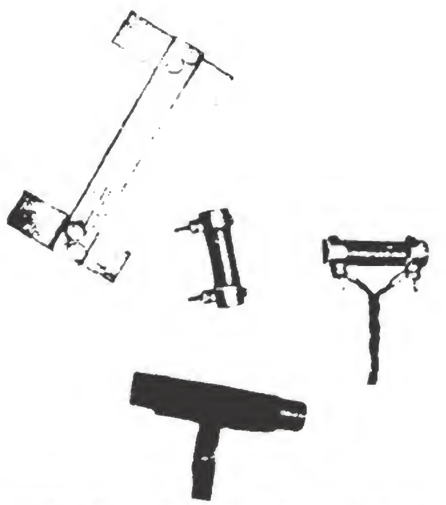
CONNECTING ANALYZER TO CIRCUITS

All cables used for connections to source or load should be of sufficient size to carry the currents involved and connected securely to the binding pots and the circuit terminals. For current up to 125 amperes use No. 2 cable; for currents up to 25 amperes use No. 12 cable; current up to 5 amperes use No. 16 cable. For more data pertaining to cables see table 4-1.

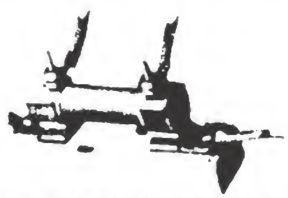
The most convenient place to make connections is at the fuse block, by using dummy fuses with cables attached (fig. 4-6). The cables connected to these dummy fuses may

Table 4-1.—Allowable Carrying Capacities of Copper Wires (Single conductor in free air)

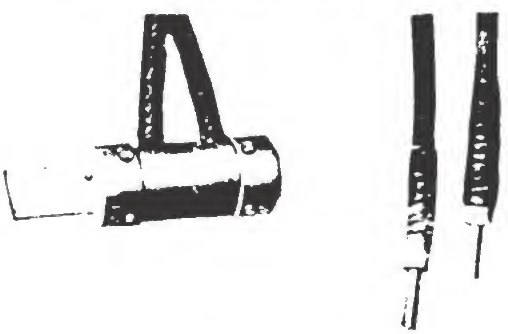
B. S. Gauge	Area in Circular Mils	Amperes
14	4,107	20
12	6,530	25
10	10,380	40
8	16,510	55
6	26,250	80
4	41,740	105
3	52,630	120
2	66,370	140
1	83,690	165
0	105,500	195
00	133,100	225
000	167,800	260
0000	211,600	300
-	250,000	340
-	300,000	375
-	350,000	420
-	400,000	455
-	500,000	515
-	600,000	575
-	700,000	630
-	800,000	680
-	900,000	730
-	1,000,000	780



VARIOUS TYPES OF CUT-OUT FUSES FOR MEASURING CURRENT WITHOUT INTERRUPTING SERVICE



"DUMMY" CARTRIDGE FUSE IN USE



26.31

Figure 4-6.—Various types of "dummy" fuzes.

be connected to the analyzer. When an interruption to service will be inconvenient, it is only necessary to remove the good fuses from the cutout and insert the dummy fuses with cables attached.

CAUTION: Disconnect the circuit by opening the main line switch before removing fuses and inserting dummy fuses. This may be done very quickly. This method is only a suggestion and may not always be practical. When using this method be certain that the circuit is protected by other fuses or circuit breakers as these dummy fuses remove the protection at that point.

Testing Single Phase Loads

The diagrams of connections shown in figures 4-7, 4-8, and 4-9 may be used for all two wire circuits.

Note in the figures mentioned above that a connection is made on the analyzer from the C to the A phase, by means of which both elements of the wattmeter are used. This is done to get as great a deflection of the wattmeter movement as possible. This is not essential as the wattmeter readings are correct regardless of whether one or both elements are used. If only one element of the wattmeter is used, the divisor of two should be omitted.

For single phase, three wire circuits the connections are the same as the three phase, three wire connections.

Three Phase Three Wire Loads

Figures 4-10 and 4-11 show the connections necessary for all three phase, three wire testing. The readings of the wattmeter are correct regardless of unbalance or power factor of the load. The readings of the power factor meter are correct for any current down to 1/5 of the full scale value.

Three Phase Four Wire Loads

As mentioned earlier, the analyzer was designed primarily for three phase, three wire loads; therefore, when three phase four wire loads are to be analyzed certain limitations are to be expected.

1. The power factor meter has been designed for balanced three phase, three wire loads. Its readings on three phase four wire loads should be disregarded.

2. The voltmeter readings will be "line to neutral" and "line to line" voltages depending upon position of voltage selector switch.

3. External current transformers must ALWAYS be used. (See fig. 4-12.)

If the three phase four wire load is balanced, with no current in the neutral wire, it may be treated as outlined for a three phase three wire load and the above limitations should be disregarded.

Regardless of the balance each phase may be treated as a single phase load and tested accordingly.

In using the external current transformers, they should have the same ranges as the transformers contained in the analyzer, that is 125, 25, or 5 amperes.

The readings of the voltmeter, using proper range and scale, represent the following:

With switch at AB, the voltage from line A to neutral.

With switch at BC, the voltage from line C to neutral.

With switch at AC, the voltage from line A to line C.

The wattmeter readings must be corrected by the multiplying factors found on the wattmeter scale.

When external potential transformers are used, as shown in figure 4-13, the readings of the voltmeter and wattmeter should be multiplied by the potential transformer ratio in addition to the above.

When currents to be measured are beyond the range of the internal current transformers the connections shown in figure 4-14 should be used.

The readings of the voltmeter, using proper range and scale, represent the following:

With switch at AB, the voltage from line A to neutral.

With switch at BC, the voltage from line C to neutral.

With switch at AC, the voltage from line A to line C.

The wattmeter readings must be corrected by the multiplying factors found on the wattmeter scale and the external current transformer ratios.

Potential connections from lines A and C are connected to the disconnect block binding posts, with the block mounted with the binding posts up.

When external potential transformers are used, as shown in figure 4-15, the readings of the voltmeter and wattmeter should be multiplied by the potential transformer ratio in addition to the above.

TRANSFORMER POLARITY TESTS

Polarity has to do only with the plan or arrangement of leads coming out of a transformer case. Interchanging the positions of the leads coming out of the case will affect the polarity of the transformer.

On a transformer wound with additive polarity, where one primary lead is connected to a secondary lead on the same side of the case as shown in figure 4-16, the voltage in the two windings is additive; that is, the sum of the applied and secondary voltages will be indicated on a voltmeter connected across X_1 and H_2. On a transformer wound with subtractive polarity, the indication on the voltmeter will be the difference of the applied and secondary voltages.

Polarity may be determined, for example, by applying 120 volts to the high-voltage side of a 10 to 1 ratio transformer. Referring to figure 4-16, V_s or the secondary voltage would equal 12 volts. With an additive polarity transformer, a voltmeter across X_1 and H_2 should read V_p plus V or 120 plus 12, which equals 132 volts. With subtractive polarity transformer, a voltmeter across X_1 and H_2 would read 120 minus 12 or 108 volts.

CAUTION: When making such tests, the voltage must not be applied across the secondary side of the transformer because the primary voltage would be equal to the applied secondary voltage times the transformer ratio. This voltage would be dangerously high to personnel and would burn out the voltmeter. Figure 4-17A and B illustrates two practical methods for testing polarity.

COMMUNICATIONS TEST EQUIPMENT

There are various testing instruments used for checking out communication circuit and equipment. However, in this section we will discuss the portable WHEATSTONE BRIDGE and the CABLE REPAIRMAN'S test set.

WHEATSTONE BRIDGE

The Wheatstone Bridge (fig. 4-18A) is used to accurately measure the resistance of electrical circuits. The basic bridge has 4 arms (A, B, R, and X). A battery energizes the bridge via S1. A central zero galvanometer is connected across opposite corners of the bridge via S2 to indicate when the bridge is balanced. The ratio arms are A and B. The variable resistance arm is R. The unknown resistance is X. When the bridge is balanced, the voltage across A is equal to the voltage across B and

$$X = \frac{A}{B}R.$$

Knowing A/B, and R and substituting in the equation you will find the value of the unknown resistance X.

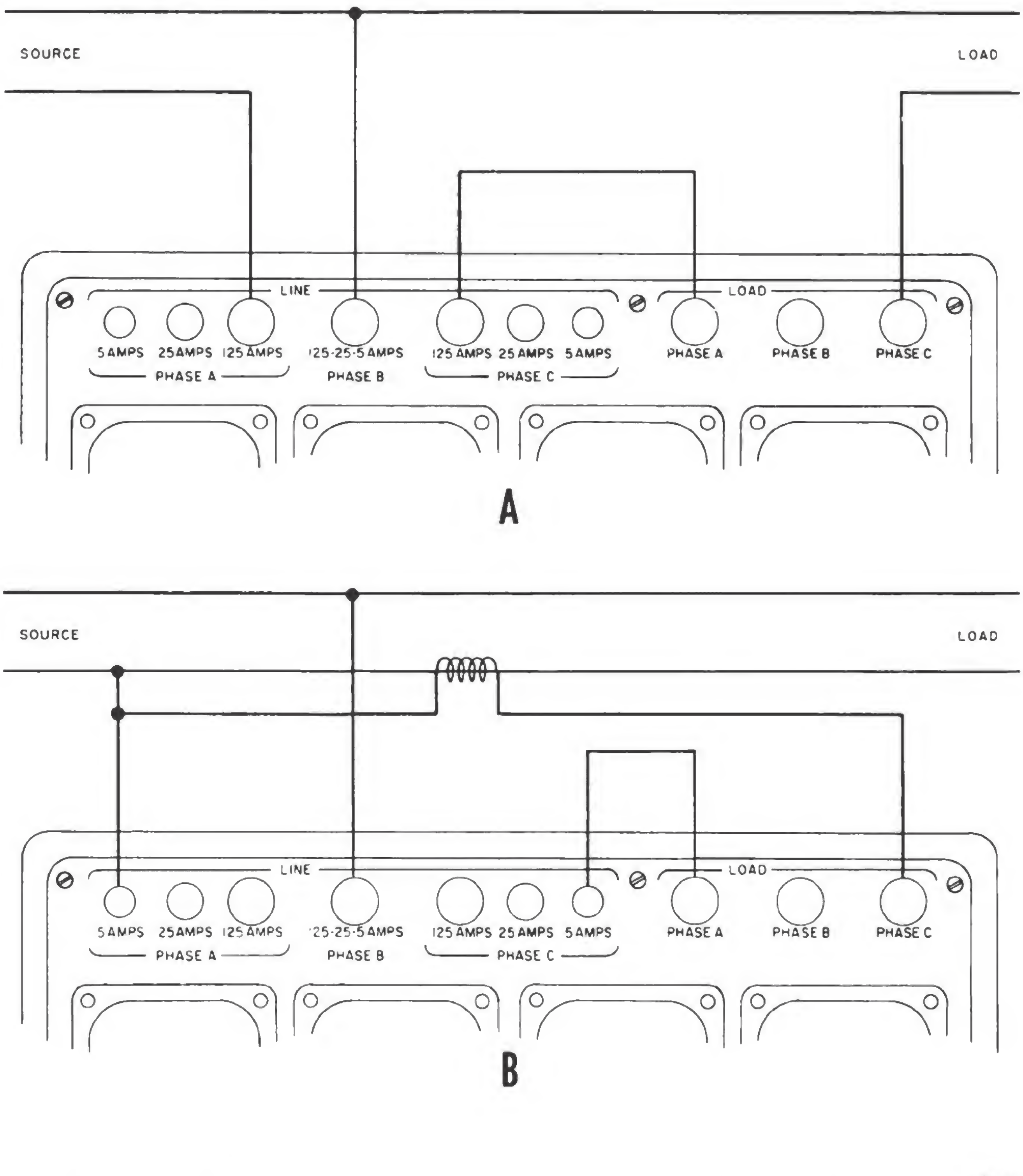
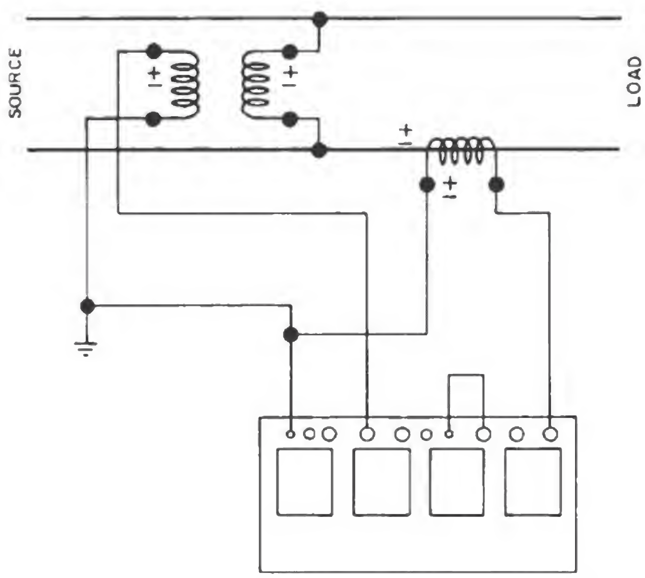


Figure 4-7.—Single phase, two wire circuit, both elements of wattmeter in series.

NOMENCLATURE - FIGURE 4-7

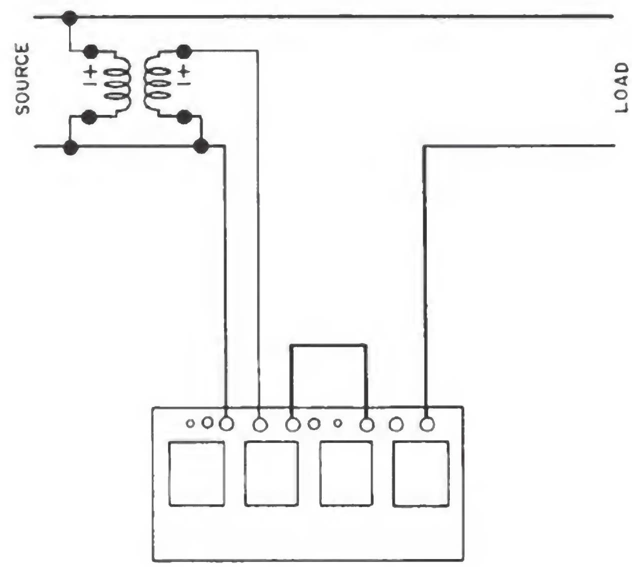
A. SINGLE PHASE, 2 WIRE CIRCUIT, both elements of wattmeter in series. Read voltage AB, current A, apply the wattmeter multiplier as found on the wattmeter scale and then divide by 2. Disregard the power factor indication.

B. SINGLE PHASE, 2-WIRE CIRCUIT using a single current transformer and with two current elements in series, read voltage AB and current A using 5 ampere scale and applying transformer multiplier. Divide kilowatt reading on 5 ampere and corresponding voltage scale by 2; then apply transformer multiplier. Disregard power factor indication.



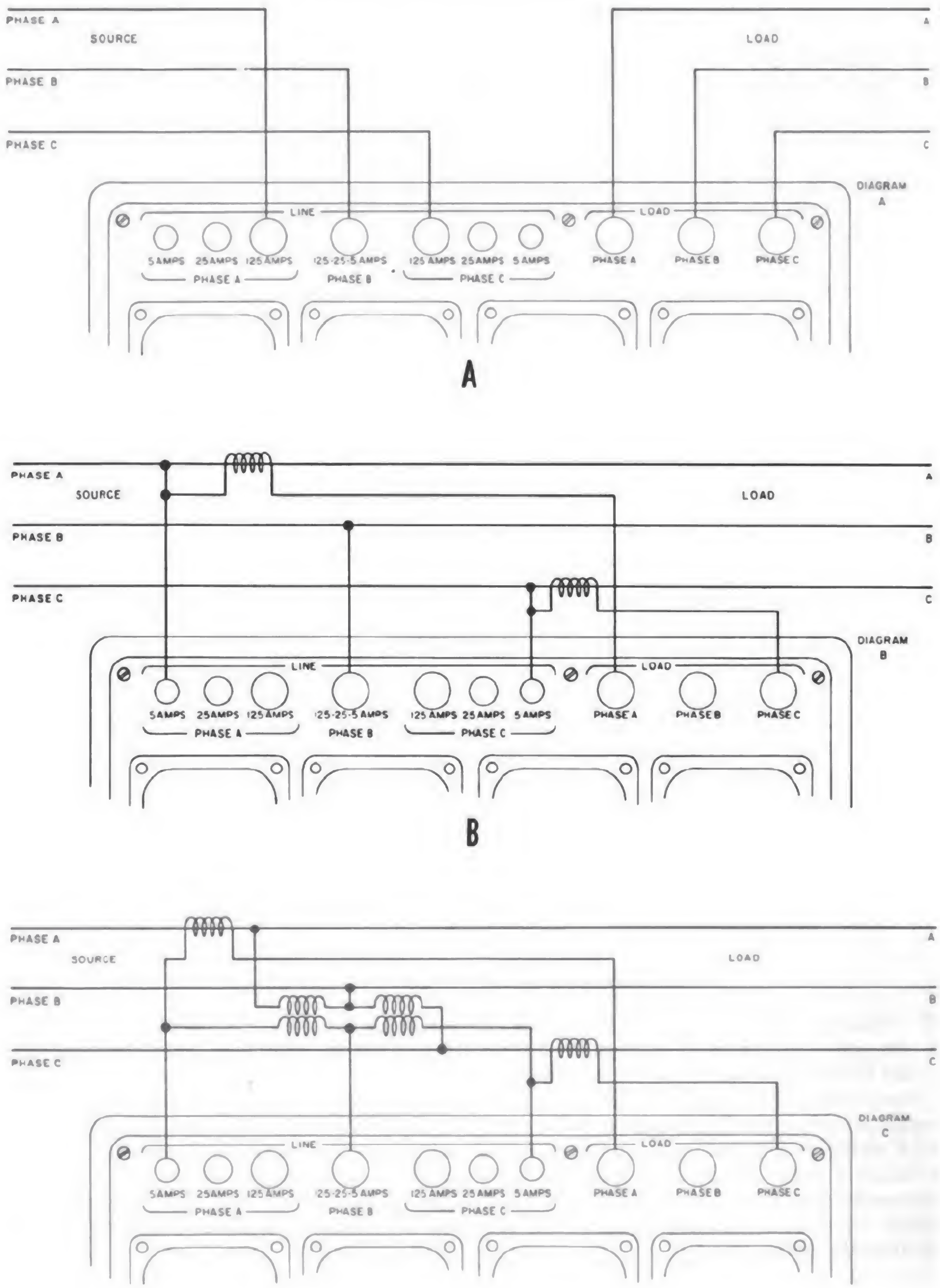
SINGLE PHASE, 2-WIRE CIRCUIT using a current transformer and a potential transformer, the current elements of the analyzer in series, read voltage AB using 150 volt range and scale, multiply by potential transformer ratio, current A using 5 ampere scale and applying current transformer ratio. Read kilowatts on scale corresponding to 5 amperes and 150 volts then divide by 2 and multiply by current and potential transformer ratios.

Figure 4-8.—Single phase, two wire circuit using a current transformer and a potential transformer.



SINGLE PHASE, 2-WIRE CIRCUIT using a potential transformer and direct connected for the current circuits with the current elements in series. Read voltage AB using 150 volt scale and range, multiply by transformer ratio. Read kilowatts on scale corresponding to 150 volts and current range selected, divide by 2 and multiply by the potential transformer ratio. Read current A using scale corresponding to range selected.

Figure 4-9.—Single phase, 2 wire circuit using potential transformer and with current elements in series.



26.35

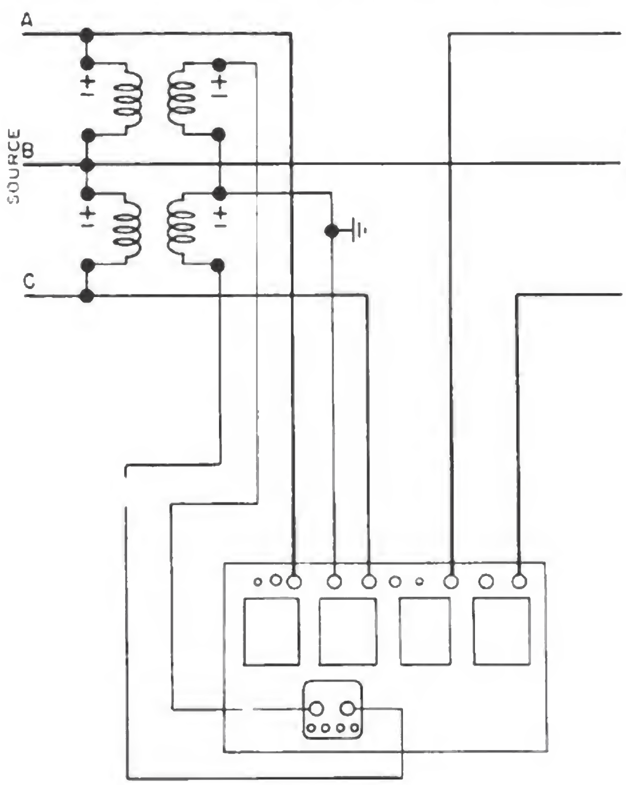
Figure 4-10.—Three phase, three wire circuit, diagram A, B, and C.

NOMENCLATURE - FIGURE 4-10

A. 3 PHASE, 3 WIRE CIRCUIT direct. Read voltage across phases as desired as well as current in any phase. Apply multiplier as given on wattmeter scale to reading as necessary for voltage and current range used. Read power factor direct.

B. 3-PHASE, 3-WIRE CIRCUIT with two current transformers. Read voltage across phases as desired and current in any wire, applying transformer multiplier to 5 ampere scale on ammeter. Apply transformer multiplier to wattmeter, also multiplying by multiplier of 1, 2 or 4, depending upon voltage range as indicated on wattmeter scale. Read power factor direct.

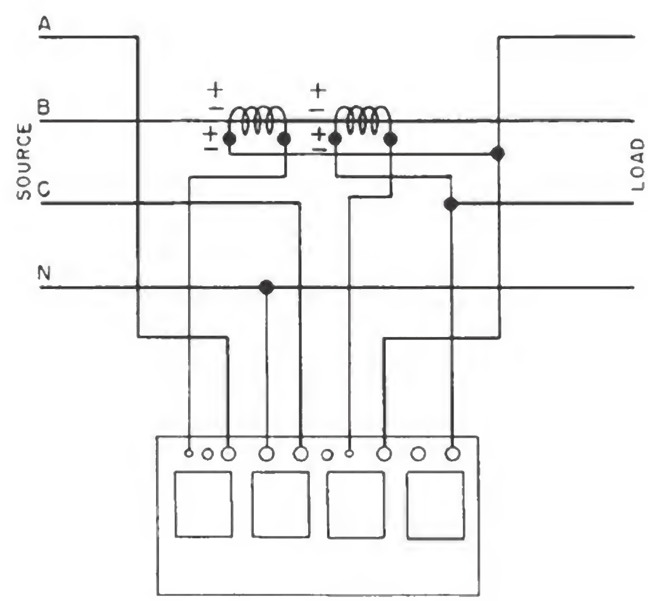
C. 3-PHASE, 3-WIRE CIRCUIT using both current and potential transformers. Read voltage across phases as desired applying potential transformer multiplier to 150 volt scale to which the voltage range switch should be set. Read ammeter in any phase applying current transformer multiplier to 5 ampere scale. Read polyphase wattmeter on 1 kilowatt scale and apply both current and potential transformer multipliers. Read power factor direct.



3-PHASE, 3-WIRE CIRCUIT with two potential transformers. Read voltage across phase as desired, use 150 volt range and apply potential transformer ratio. Read ammeter in any phase direct for range selected. Read wattmeter scale, use multiplying factor for current and potential ranges selected, then multiply by potential transformer ratio.

26.36

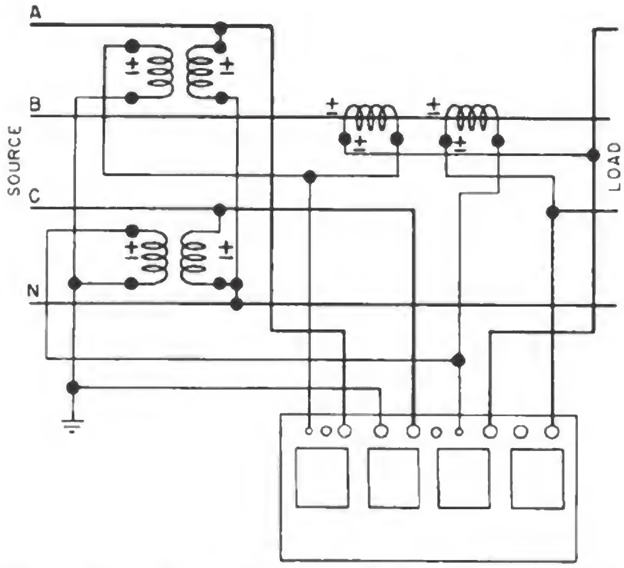
Figure 4-11.—Three phase, three wire circuit with two potential transformers.



3-PHASE, 4-WIRE CIRCUIT. Two identical current transformers of suitable range having 5 ampere secondaries are connected in the "B" phase as shown.

26.37

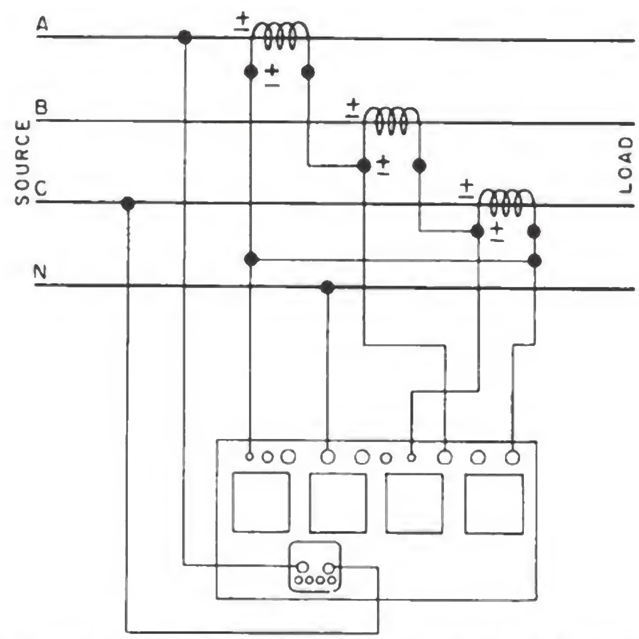
Figure 4-12.—Three phase, four wire circuit having two identical current transformers.



3-PHASE, 4-WIRE CIRCUIT. Two potential transformers having 115 volt secondaries, connected from neutral to lines "A" and "C". Two current transformers of suitable range having 5 ampere secondaries.

26.38

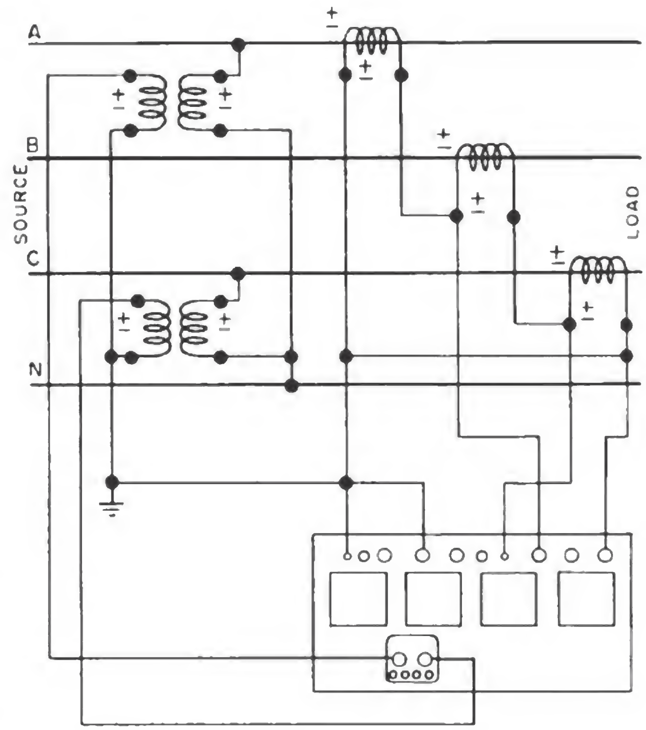
Figure 4-13.—Three phase, four wire circuit with two potential transformers.



3-PHASE, 4-WIRE CIRCUIT. Potential direct connected. Three current transformers of suitable range having 5 ampere secondaries delta connected.

26.39

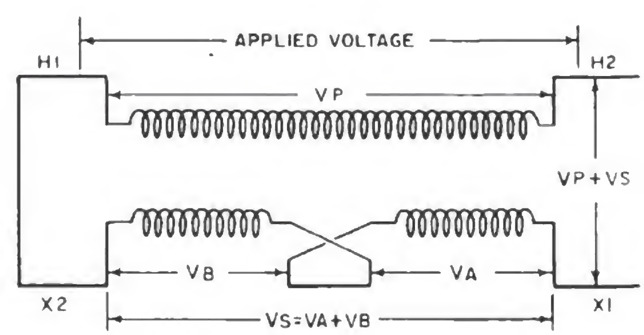
Figure 4-14.—Three phase, four wire circuit with potential directly connected.



3-PHASE, 4-WIRE CIRCUIT. Two potential transformers of suitable range having 115 volt secondaries connected from neutral to lines "A" and "C". Three current transformers of suitable range having 5 amperes secondaries connected in delta.

26.40

Figure 4-15.—Three phase, four wire circuit connected to three current transformers.



26.41

Figure 4-16.—Polarity test example for additive polarity.

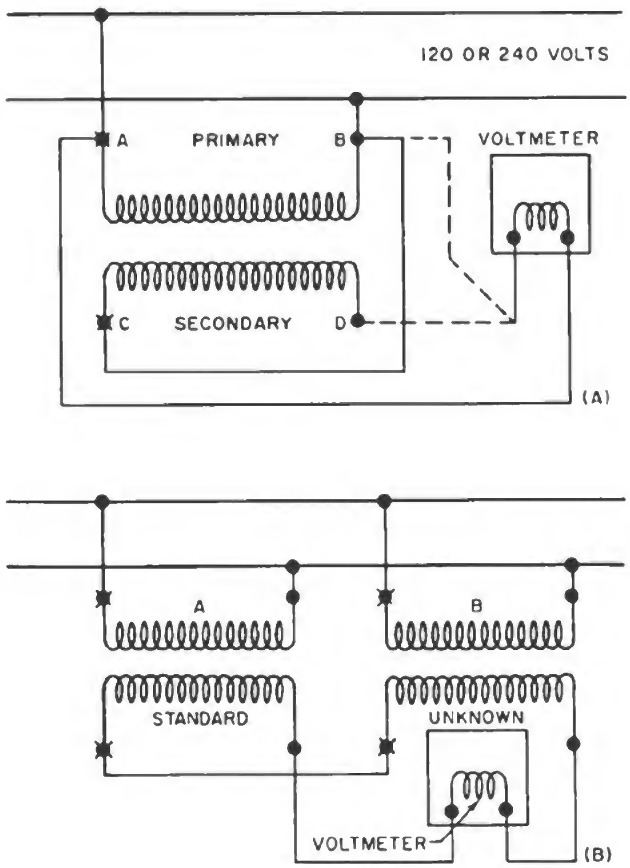


Figure 4-17.—More practical methods for testing polarity.

A. Voltage measured from A to D is greater than voltage from A to B if polarity markings are correct.

B. Voltage measured across two unmarked terminals equals zero if polarity markings are correct. Otherwise, measured voltage is twice normal secondary voltage.

The Wheatstone bridge (fig. 4-18, B and C) may be used to measure the resistance (Res) of a pair of wires in a telephone cable. It may also be used to locate the distance to a fault (ground) in the cable by either of two methods, the Varley (Var) loop test or the Murray (Mur) loop test.

Before using the Wheatstone bridge, it is important that you place it on a level surface as near as practicable to the test point, then make the following operational test:

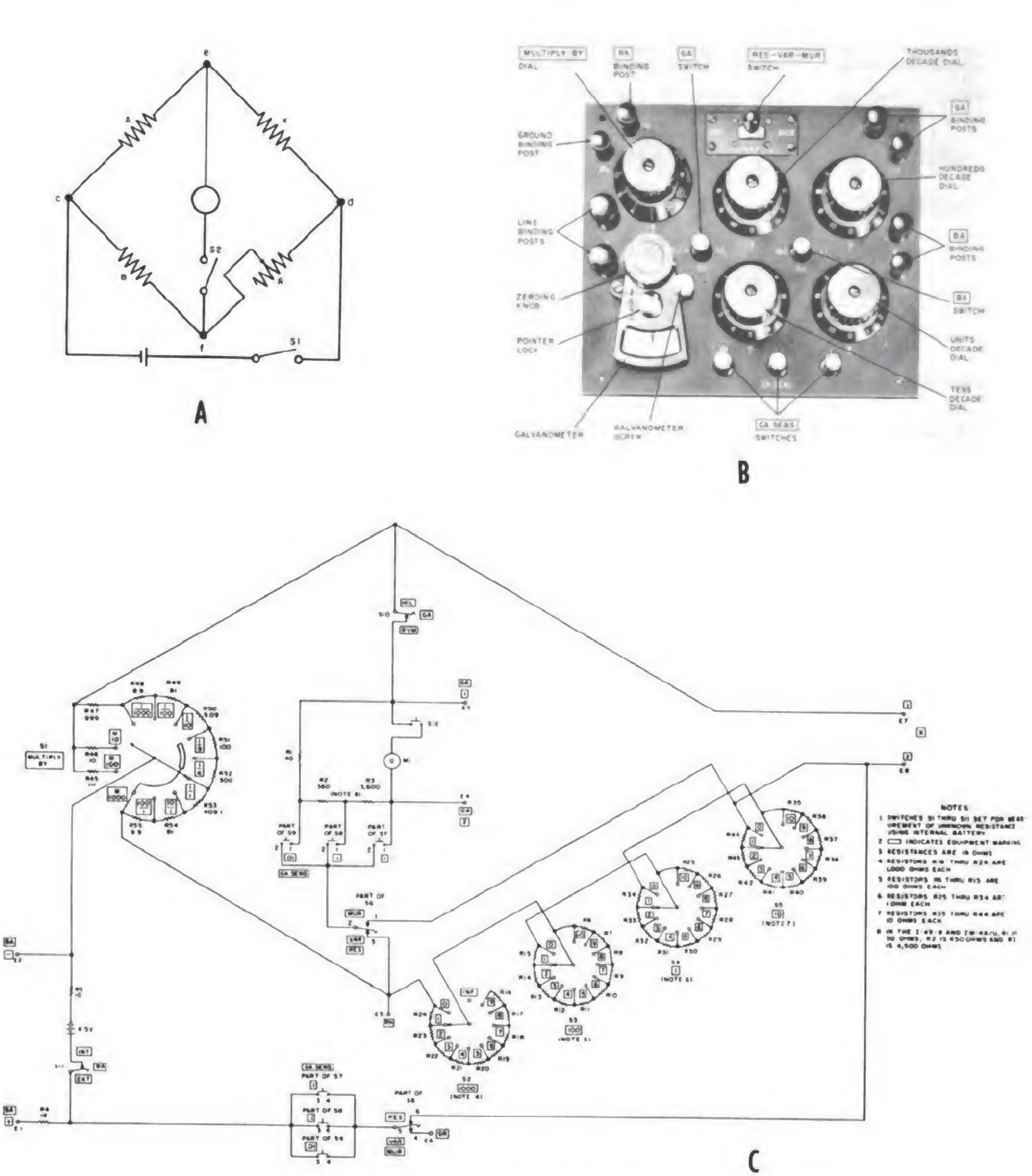
1. Position the following controls as indicated:
   a. GA switch to RVM.
   b. RES-VAR-MUR switch to RES.
   c. MULTIPLY BY dial to 1/1.
   d. Units, hundreds and thousands decade dials to 0.
   e. Tens decade dial to 5.
2. Connect a jumper across line binding posts X1 and X2.
3. Press the GA SENS .01 switch and release it immediately. If the pointer of the galvanometer deflects to the left (—) and returns to zero, the test set is ready for use. If the pointer deflects to the right (+), reverse the polarity of the power source. If the pointer does not deflect in either direction, the test set is faulty and maintenance is required.

MEASUREMENT OF UNKNOWN RESISTANCE

To measure the resistance of a loop (two lengths of wire joined at the distant end) or any electrical component (such as resistors and transformers) do the following:

1. Galvanometer adjustment. Adjust the galvanometer by sliding the pointer lock toward the meter scale as far as it will go. If the pointer does not balance at the center of the scale, loosen the galvanometer screw, adjust the zeroing knob until the pointer balances at the center of the scale, and tighten the galvanometer screw.
2. Position the test set controls as follows:
   a. GA switch to RVM.
   b. RES-VAR-MUR switch to RES.
   c. Make as close an estimate as possible of the resistance to be measured and set the MULTIPLY BY dial as indicated in table 4-2.
3. Make the following connections:

a. If the resistance of a loop is to be measured, disconnect all equipment from the near end of the loop and connect one wire of the loop to line binding post X1 and the other wire to line binding post X2 (fig. 4-19). Be sure that the wires connected to the test set are clean and are firmly secured to the binding posts. Have all equipment disconnected from the far end of the loop and a short placed across the circuit at that end. If the resistance of an electrical component is to be measured, connect the component across line binding posts X1 and X2.



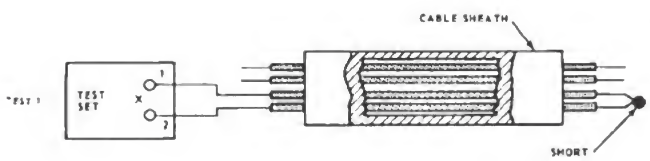
A. Basic bridge circuit. B. Operating controls. C. Schematic

Figure 4-18.—Wheatstone Bridge.

26.43

Table 4-2. Multiply By Dial Setting When Measuring Resistance.

Estimated Resistance (ohms)	Multiply By Dial Setting
Below 10	$\frac{1}{1000}$
10 to 100	$\frac{1}{100}$
100 to 1000	$\frac{1}{10}$
1000 to 10,000	$\frac{1}{1}$
10,000 to 100,000	$\frac{10}{1}$
100,000 to 1,011,000	$\frac{100}{1}$



26.44
Figure 4-19.—Connection for measurement of loop resistance.

4. To balance the bridge, position the thousands, hundreds, tens and units decade dials to settings that total the estimated resistance to be measured divided by the setting of the MULTIPLY BY dial.

EXAMPLE: If the estimated resistance to b. measured is 500 ohms, the setting of the MULTIPLY BY dial must be 1/10 (table 4-3); therefore the positions of the decade dials must total 5000.

$$\frac{\text{Estimated resistance to be measured}}{\text{Setting of MULTIPLY BY dial}} = \frac{500}{1/10} = 5000$$

Press the GA SENS .01 switch and note the direction of movement of the galvanometer pointer. If it moves to the right, increase the resistance total of the decade dials until it does not move from zero when the GA SENS 0.1 switch is pressed. If the pointer moves to the left, decrease the resistance total of the decade dials. Repeat the above procedure, using the GA SENS .1 and then the GA SENS 1 switches. The test procedure is completed when the GA SENS 1 switch is pressed and the pointer does not move in either direction. Under these conditions, the bridge circuit in the test set is said to be balanced.

5. To determine **the resistance, take** the sum of the decade dial settings multiplied by the setting of the MULTIPLY BY dial.

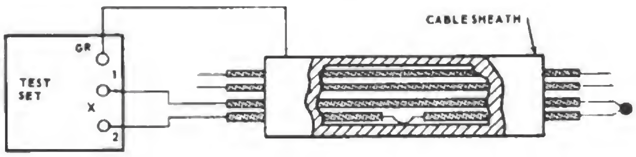
EXAMPLE: If the bridge is balanced when the sum of the decade dial settings is 5137 and the MULTIPLY BY dial is set at 1/10, the resistance connected across the line binding posts is 5137 x 1/10 or 513.7 ohms (decimal point moved one place to the left). If the MULTIPLY BY dial is set at 1/100, move the decimal point two places to the left (51.37 ohms); for 1/1000, move the decimal point three places to the left (5.137 ohms). For 10/1, add one zero to the reading (51,370 ohms) and for 100/1, add two zeros (513,700 ohms).

REGULAR VARLEY LOOP TEST

The regular Varley loop test (fig. 4-20) is used to locate a ground in a high-resistance loop when the unbalance (difference in resistance between the faulty and good wires) does not exceed 1 ohm. The regular Varley method requires the use of one good wire between the test point and the far end of the circuit.

Locate the ground as follows:

1. Adjust the galvanometer and remove all equipment from both ends of the faulty circuit.
2. Measure and record the loop resistance, r. In this example assume r = 5525 ohms.
3. Position the test set controls as follows:
   a. Ga switch to RVM
   b. RES-VAR-MUR switch to VAR
   c. MULTIPLY BY dial to 1/4
4. Make the following connections:
   a. Connect the ground binding post to a good ground connection (fig. 4-20). This will be the cable sheath since the fault is assumed to be in lead covered cable.



26.45

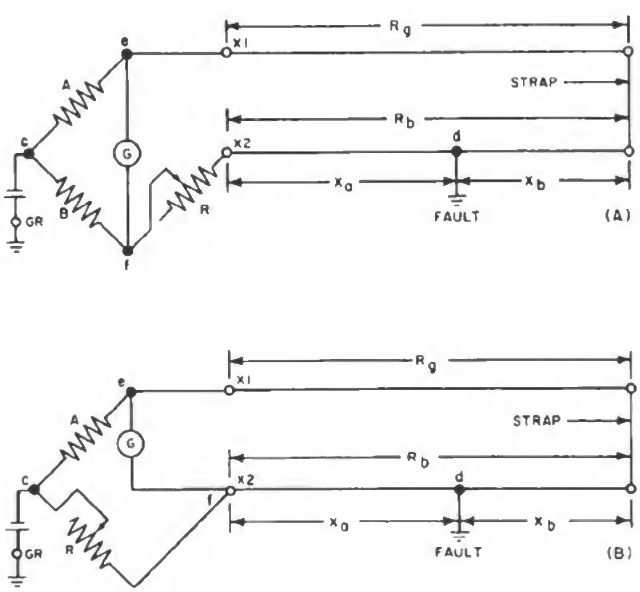
Figure 4-20.—Connections for ground location, regular Varley and Murray loop tests.

b. Connect the grounded wire to line binding post X2.
c. Connect the ungrounded wire to line binding post X1.
d. Have a short placed across the far end of the grounded circuit (fig. 4-20).

5. Adjust the decade dials to balance the bridge and record the sum of the decade dials, R. In this example assume R = 9560 ohms.

6. Compute the resistance X_a from test point to ground fault (fig. 4-21, A) using the following formula:

$$X_a = \frac{rB - AR}{A + B}$$



A. Varley loop test.
B. Murray loop test.

26.46

Figure 4-21.—Simplified schematics for locating grounds.

a. In this example r = 5525 ohms

A/B = 1/4
A = 1
B = 4
R = 9560 ohms

Substituting these values in the formula

$$X_a = \frac{5525 \times 4 - 1 \times 9560}{1 + 4}$$

$$= \frac{22{,}100 - 9560}{5}$$

$$= \frac{12{,}540}{5} = 2508 \text{ ohms}$$

b. Compute the resistance X_b from the far end to the ground fault using the formula,

$$X_b = \frac{A\,(R + R_b) - BR_g}{A + B}$$

In this example A = 1, B = 4, $R_b = R_g = r/2 = 5525/2 = 2762.5$ ohms and R = 9560 ohms.

Substituting these values in the above formula:

$$X_b = \frac{1(9560 + 2762.5) - 4 \times 2762.5}{1 + 4}$$

$$= \frac{12{,}322.5 - 11{,}050}{5}$$

$$= \frac{1272.5}{5} = 254.5 \text{ ohms}$$

7. Compute the distance d_a from the test set to the fault using the formula:

$$d_a = \frac{X_a}{1/2 \text{ resistance per loop mile}}$$

where resistance per loop mile

$$= \frac{r}{\text{distance from test set to far end}}$$

In this example r = 5525 ohms, and distance from test set to far end = 65 miles

Resistance per loop mile ohms $= \frac{5525}{65} = 85$

X_a = 2508 ohms.

Substituting these values in the above formula:

$$d_a = \frac{2508}{1/2 \text{x} 85}$$

$$= \frac{2508}{42.5}$$

= 59.01 miles from test set to ground fault.

Compute the distance d_b in miles from the far end to the ground fault using the formula:

$$d_b = \frac{X_b}{1/2 \text{ resistance per loop mile}}$$

In this example X_b = 254.5 ohms (from 6b above) and the resistance per loop mile is 85 ohms (from 7). Substituting these values in the above formula and solving for d_b

$$d_b = \frac{254.5}{1/2 \text{x} 85}$$

$$= \frac{254.5}{42.5} = 5.99 \text{ miles}$$

8. Make a check on your work as follows:
   a. Reverse the wires connected to X1 and X2 of figure 4-20.
   b. Adjust the decade dials to balance the bridge and record the sum, R_2, of the decade dials. Use the following formula to determine the resistance X_a from the test point to the ground:

$$X_a = \frac{A(R2+r)}{A+B}$$

In this example R_2 = 7015 ohms.

A = 1, B = 4, r = 5525 ohms

Substituting these values in the above formula and solving for X_a,

$$X_a = \frac{1\text{x}(7015+5525)}{1+4}$$

$$= \frac{12,540}{5} = 2508 \text{ ohms (same as 6a)}$$

MURRAY LOOP TEST FOR LOCATING A GROUND

To use the Murray loop test for locating a ground a good wire should be available (fig. 4-20) in addition to the grounded wire. Remove all equipment from both ends of the circuit and locate the fault as follows:

1. Adjust the galvanometer.
2. Position the test set controls as follows:
   a. GA switch to RVM
   b. RES-VAR-MUR switch to MUR
   c. MULTIPLY BY dial to M1000.
3. Make the following connections (fig. 4-20 and 4-21B):
   a. Connect the grounded wire to line binding post X_2.
   b. Connect the good wire to line binding post X_1.
   c. Connect the ground binding post to a good ground (cable sheath).
   d. Have a short placed across the far ends of the wires connected to line binding posts X_1 and X_2.

4. Balance the bridge and record the decade dial reading.

In this example the bridge is balanced with the MULTIPLY BY dial set at M = 1000 and the total decade dial reading, R = 600 ohms.

5. Use the direct computation method by solving for the distance d_a from the test point to the fault using the formula

$$d_a = \frac{R\text{x}L}{R+A}$$

   a. In this example R = 600, L = total length of loop = 8 miles and A = 1000 = MULTIPLY BY dial reading. Substituting these values in above formula:

$$d_a = \frac{600\text{x}8}{600+1000}$$

$$= \frac{4800}{1600} = 3 \text{ miles}$$

b. Use the resistance-distance method of computing the distance, d_a, from the test point to the fault as follows:

(1) Measure and record the loop resistance of the faulty circuit. In this example the loop resistance, r, is measured and found to be 370.4 ohms.

(2) Use the following formula to compute the resistance, X_a, (fig. 4-21B) from the test point to the fault.

$$X_a = \frac{Rxr}{R+A}$$

In this example R = 600 ohms, r = 370.4 ohms and A = 1000. Substituting these values in the above formula and solving for X_a,

$$X_a = \frac{600x370.4}{600+1000}$$

$$= 138.9 \text{ ohms}$$

(3) Use the following formula to compute the distance, d_a, from the test point to the fault:

$$d_a = \frac{X_a}{1/2 \text{ resistance per loop mile}}$$

where the resistance per loop miles

$$= \frac{r}{\text{distance from test point to far end}}$$

In this example r = 370.4 ohms total resistance of loop and the distance from the test point to the far end is 4 miles. The resistance per loop mile = $\frac{370.4}{4}$ = 92.6 ohms. Substituting these values in the above formula

$$d_a = \frac{138.9}{1/2x92.6}$$

$$= \frac{138.9}{46.3} = 3 \text{ miles}$$ (same as 5a above)

(4) To make a check test, reverse the wires connected to line binding posts X_1 and X_2 (fig. 4-20) balance the bridge and use the following formula to determine the resistance, X_a, from the test point to the fault. (The computed resistance should be the same value as in 5b (2) above).

$$X_a = \frac{A x r}{A + R_2}$$

In this example, R_2 = 1666 ohms and r = 370.4 ohms. Substituting these values in the above formula and solving for X_a:

$$X_a = \frac{100x370.4}{1000+1666}$$

$$= \frac{370,400}{2666}$$

= 138.9 ohms (same as in 5b (2)). above).

PREVENTIVE MAINTENANCE

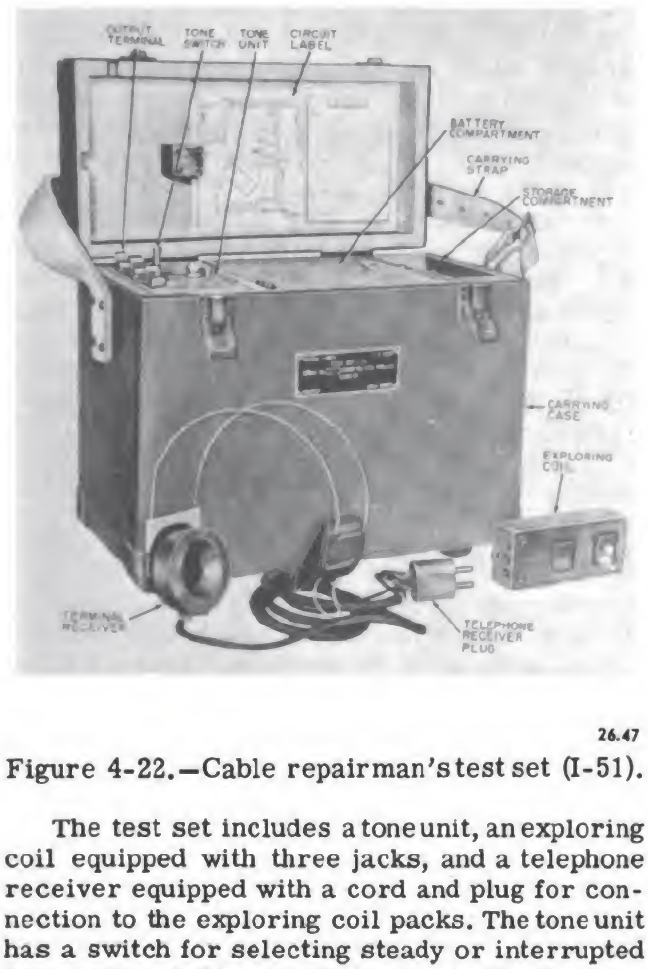
The Wheatstone bridge like most meters should be inspected, cleaned, and tested at least once a year. However, if the test set is used often it may be necessary to inspect and clean it more often.

In order to perform preventive maintenance you should remove the screw in each corner of the panel and lift the panel from the carrying case to permit inspection and cleaning of the test set interior. Examine the contact surface of the five dial switches carefully. If dirty, wipe the surfaces clean with a cloth slightly moistened with cleaning compound and wipe dry. Apply a light coat of petroleum on the switch contact surfaces, and wipe the surfaces slightly with a clean cloth to leave a very thin film of lubricant on the surfaces. Replace the panel in the carrying case and check for normal operation.

WARNING: Cleaning compound is flammable and its fumes are toxic. Do not use near a flame and be sure adequate ventilation is provided.

CABLE REPAIRMAN'S TEST SET

The cable repairman's test set (fig. 4-22) is used to pinpoint the location of cable faults after the approximate location of the fault has been obtained by the use of the Wheatstone bridge or some other method. The test set can be used to locate shorts, grounds, crosses, split pairs, wet spots, and similar troubles in a cable. IT CANNOT BE USED TO LOCATE OPEN CIRCUITS.



26.47

Figure 4-22.—Cable repairman's test set (I-51).

The test set includes a tone unit, an exploring coil equipped with three jacks, and a telephone receiver equipped with a cord and plug for connection to the exploring coil packs. The tone unit has a switch for selecting steady or interrupted tone and a set of terminals for connecting the tone unit to the faulty conductors. These units are housed in a carrying case which is provided with an adjustable carrying strap. The inside of the carrying case is divided into three compartments: one for the tone unit, one for the batteries, and one for storing the exploring coil and the receiver. In addition to the components supplied with the test set, it is necessary to have 4 (BA-23) batteries to furnish the required 6 volts, two alligator clips and approximately 10 feet of two-conductor cable required to assemble the test cord.

OPERATING PROCEDURES

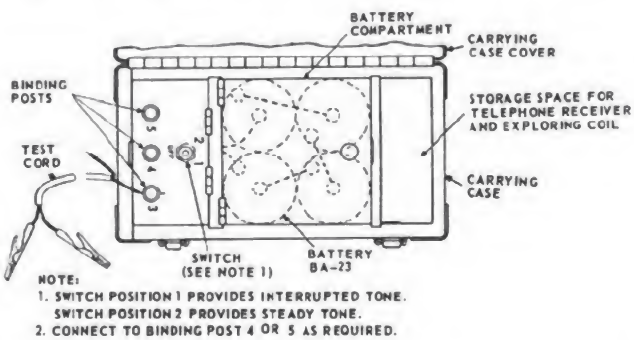
Before you proceed to use the test set, you should first obtain information from the central office personnel on the type of cable fault, the resistance of the faulty conductors, and the aproximate location of the fault.

LOCATION OF GROUNDS

In locating grounds with the test set you will proceed in the following manner:

1. Connect the alligator clip of one output terminal (binding posts) of the test set to the cable sheath and the other to the grounded conductor (fig. 4-24).

NOTE: The other end of the test cord is connected to the output terminals (binding posts) of the test set. Use binding posts 3 and 4 for cable faults having a resistance of less than 100 ohms between the point where the tone is applied and the probable location of the trouble. Use binding posts 3 and 5 for cable faults having a resistance of 100 ohms or more. (Regardless of how much resistance on the fault, binding post 3 is always used.) (See fig. 4-23.)

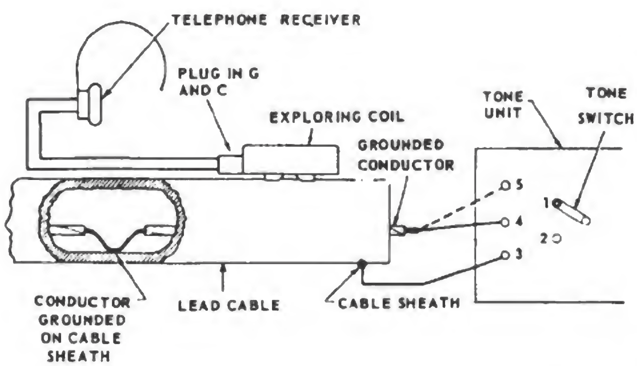


26.48

Figure 4-23.—Test set, top view with cover open.

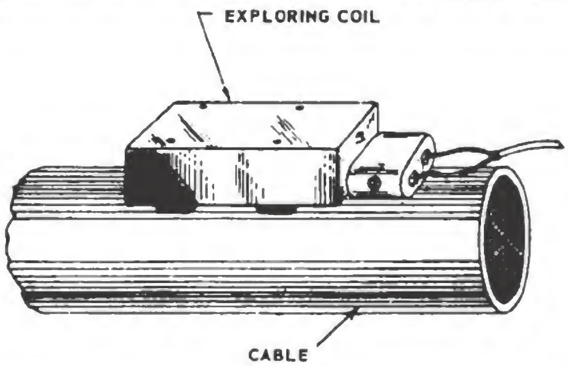
2. Set the tone switch to position 1 (fig. 4-24).

3. At the approximate location of the fault, place the telephone receiver in position over one ear and hold the exploring coil parallel to the cable as shown in figure 4-25. Be sure that the



26.49

Figure 4-24.—Connections for locating grounds.



26.50

Figure 4-25.—Position of exploring coil for locating grounds, shorts, or split pairs.

telephone receiver plug is inserted into the G and C jacks of the exploring coil.

4. While listening with the receiver, move the exploring coil along the cable toward the fault until the tone disappears or the volume of the tone is markedly decreased, which indicates the exact location of the fault.

NOTE: In high resistance faults, the tone will not disappear when the fault is passed because of a carry-over effect of the line capacitance. In some cases, the change in volume is so slight that an absolute location of the fault is uncertain. In such cases, place a chalk mark at the approximate location, then transfer the test set to the other end of the cable, and repeat the steps given above.

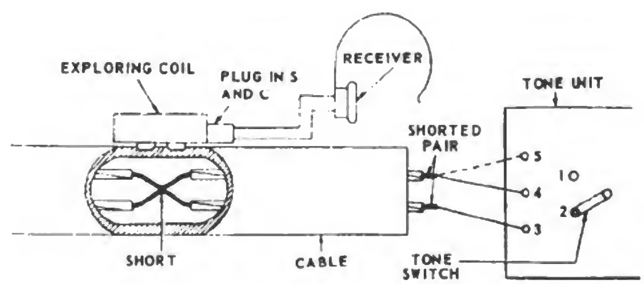
LOCATION OF SHORTS

A short circuit is caused by an insulation breakdown between the two conductors of a pair allowing the two wires to touch each other. A high resistance short may occur if moisture enters the cable sheath and reduces the insulation resistance between the two wires of the pair to the point where the conductors cannot be used efficiently.

In locating shorts with the cable repairman's test set you will proceed in the following manner:

1. Connect the alligator clip of one output terminal of the test set to the cable sheath and the other to the grounded conductor. (See note under 1, Location of Grounds.)
2. Set the tone switch to position 2.
3. At the approximate location of the fault, place the telephone receiver plug in position over one ear and hold the exploring coil parallel to the cable as shown in figure 4-25. Be sure that the telephone receiver plug is inserted in S and C jacks of the exploring coil.
4. While listening with the receiver, move the exploring coil along the cable toward the fault. The tone will decrease and increase in volume as the coil is moved along the cable. This is called the short-circuited effect. When the coil is moved over the fault, the tone either will decrease considerably in volume or disappear entirely.

NOTE: If uncertain of the exact location, then transfer the test set to the other end of the cable and repeat the steps given above. (Connections for locating shorts shown in fig. 4-26.)



26.51

Figure 4-26.—Connection for locating shorts.

LOCATION OF CROSSES

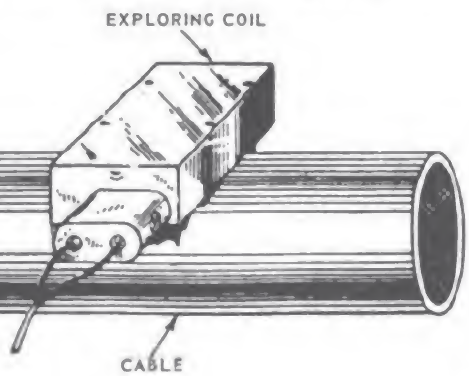
A cross is essentially the same as a short except that the contact is between conductors from two different pairs.

To locate crossed wires you will proceed in the following manner:

1. Connect the alligator clips of the output terminal to the crossed conductors. (See note under 1, Location of Grounds.)

2. Set the tone switch to position 1.

3. At the approximate location of the fault, place the telephone receiver in position over one ear and hold the exploring coil at a right angle to the cable as shown in figure 4-27. Be sure that the telephone receiver plug is inserted into the S and C jacks of the exploring coil.

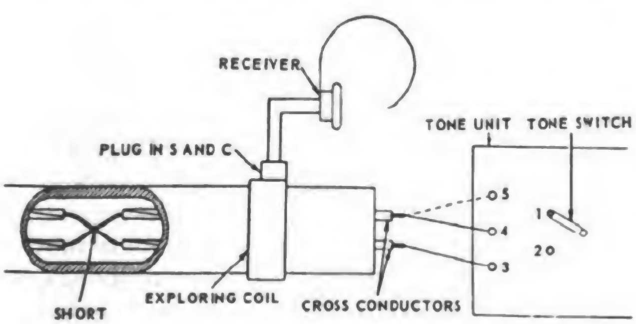


26.52

Figure 4-27.—Position of exploring coil for locating crosses and wet spots.

4. While listening with the receiver, move the exploring coil along the cable toward the fault until the tone fades out or is reduced considerably in volume. The steady volume tone heard while tracing crossed wires is known as the crossed-wires effect. (Connections for locating crossed wires is shown in fig. 4-28.)

NOTE: If uncertain of the exact location of the fault, place a chalk mark at the approximate location, then transfer the test set to the other end of the cable and repeat the steps given above.



26.53

Fig. 4-28.—Connections for locating crossed wires.

LOCATION OF SPLIT PAIRS

A split pair is caused by splicing error in which one wire of a pair is connected to one wire of another pair.

In locating a split pair you will proceed in the following manner:

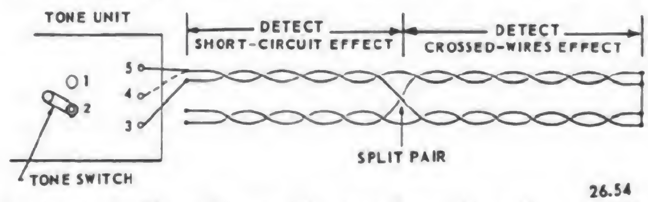
1. Strap the four wires of the two split pairs together at the far end of the cable.

2. Connect the alligator clips of the output terminals to one of the split pairs. (See NOTE under 1, Location of Grounds.)

3. Set the tone switch to position 2.

4. At the approximate location of the fault, place the telephone receiver in position over one ear and hold the exploring coil parallel to the cable as shown in figure 4-25.

5. While listening with the receiver, move the exploring coil along the cable toward the fault. The tone will increase and decrease in volume (short-circuit effect) up to the location of the fault and, thereafter, will be steady in volume (crossed-wires effect). (Connection for locating split pairs is shown in fig. 4-29.)



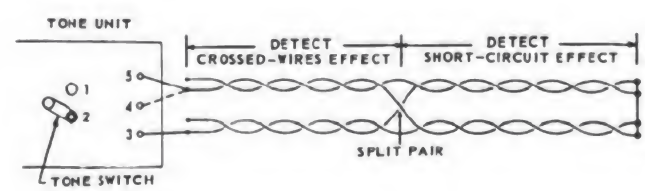
26.54

Figure 4-29.—Connections for locating split pairs.

6. To ensure accurate location of the fault, mark the cable at the location found in 5 above, and then use the alternative method of locating split pairs as a check.

ALTERNATIVE METHOD OF LOCATING SPLIT PAIRS

1. Connect the alligator clips of the output terminals of the test set to one wire of one of the split (strapped at the far end of the cable) and to one wire of the other pair as shown in figure 4-30.



26.55

Figure 4-30.—Alternative connections for locating split pairs.

2. Set the tone switch to position 2.

3. While listening with the receiver, move the exploring coil along the cable toward the fault. The tone will be steady in volume (crossed-wire effect) until the fault is reached; thereafter the tone will increase and decrease in volume (short-circuit effect).

NOTE: It is possible to connect the test set in such a manner that the short-circuit effect will not be detected. If this happens, reconnect one of the test leads to the other wire of the pair to which it is connected. The short-circuit effect now should be heard as described above.

LOCATION OF WET SPOTS

Normally a wet spot in a cable is caused by an opening in the cable sheath. In aerial cables, this opening can be caused by squirrels chewing on the cable sheath or by tree limbs, cable rings, or cable lashing wire rubbing against the sheath. In underground cables, an opening in the sheath normally is caused by soil erosion or electrolysis. When opening appears in the sheath, moisture eventually enters the cable and forms a combination of grounds, short circuits, and crosses.

In locating wet spots with the test set, you will proceed in the following manner:

1. Connect the alligator clips of the output terminals to each group of strapped wires (fig. 4-31).

2. Set the tone switch to position 1.

3. At the approximate location of the fault place the telephone receiver in position over one ear and hold the exploring coil at right angles to the cable as shown in figure 4-27. Be sure that the telephone receiver plug is inserted into the S and C jacks of the exploring coil.

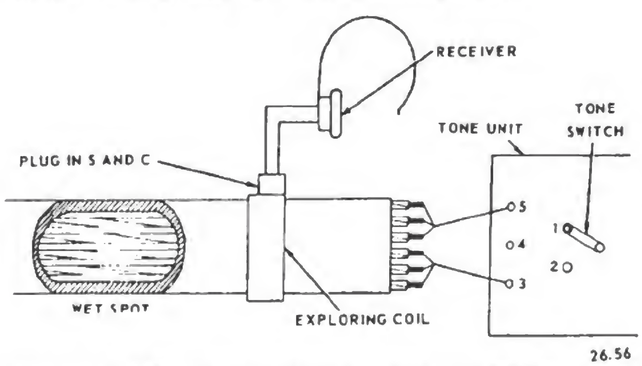


Figure 4-31.—Connections for locating wet spots.

4. While listening with the receiver, move the exploring coil along the cable toward the fault. A steady tone will be heard up to the location of the fault and, thereafter, the tone either will decrease considerably in volume or disappear entirely.

5. To ensure accurate location of the fault, mark the cable at the location found in 4 above, and use the alternative method of locating wet spots as a check.

ALTERNATIVE METHOD FOR LOCATING WET SPOTS

1. Strap together one group of wires which has a low resistance to ground.

2. Connect the alligator clip of one output terminal of the test set to the cable sheath and the other to the strapped group of wires (1 above).

3. Leave the tone switch set to position 1.

4. At the approximate location of the fault, place the telephone receiver in position over one ear and hold the exploring coil parallel to the cable as shown in figure 4-25. Be sure that the telephone receiver plug is inserted into the G and C jacks of the exploring coil.

5. While listening with the receiver, move the exploring coil along the cable toward the fault until the tone disappears or the volume of the tone is markedly decreased, which indicates the exact location of the fault.

LOCATION OF BURIED CABLE

It sometimes becomes necessary to trace the path of a buried cable, the location of which is not known. Also, when there is trouble in a buried cable, much excavation may be avoided if the exact location of the cable can be determined. Only the tracing methods directly applicable to buried cable are discussed in this section.

In conjunction with the cable repairman's test set I-51, the following items of equipment are required for tracing buried cable:

Amplifier . . .	BC-1388
Coil	Bicycle wheel exploring coil No. 46 induction coil
Receivers . . .	Two No. 716-D receivers equipped with a WECo R2CF cord and a WECo 11A headband.
Rods.	Two ground rods, GP-26

The exploring coil is not available as a standard item, but can be constructed locally as follows:

Wind approximately 300 turns of No. 24-gage double cotton-covered copper wire in the groove of a wooden bicycle rim with a diameter of 24 or 26 inches. Then bring the two ends of the windings through two small holes drilled about 1/2 inch apart in the side of the rim. Wrap a layer of rubber tape and then a layer of friction tape in the reverse direction over the rim and wire, bringing the ends of the wire out of the coil between the layer of the tapes. Terminate the ends of the winding by soldering them to binding posts mounted in a small insulating strip. A piece of hard rubber 3/16 inch by 3/4 inch by 2 1/2 inches will serve satisfactorily as the strip. Apply two coats of asphalt paint to the entire coil. Then fasten the terminal strip to the inside of the wood rim.

In an emergency any fine-gage insulated wire wound into a coil about 2 feet in diameter can be used in place of the coil described above.

Under some conditions, the pick-up of the exploring coil will be sufficient to give a suitable signal when connected directly to the No. 716-D receivers. If the signal is not strong enough to permit tracing, an amplifier, such as the BC-1388, is connected to the listening circuit. Figure 4-32 shows a schematic view of the exploring coil.

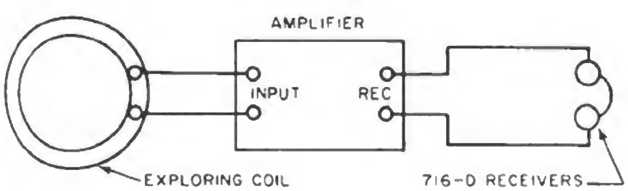


Figure 4-32.—Exploring for tracing buried cable.

Stray Current Method of Tracing Conductor

In locating and tracing the path of a buried cable or a conductor which is not readily accessible, it is generally advisable first to attempt to make a location by the stray current method with the coil held in a horizontal position. Walk across the approximate path of the conductor to determine whether there is sufficient stray current flowing to give an audible signal or tone in the receivers. If there is, the tone volume will rise gradually to a maximum as the conductor is approached, suddenly fall to a low value when the coil is directly over the conductor, rise again to previous maximum as the conductor is passed, and then decrease slowly. If the exploring is done in the proximity of a power line, most of the tone heard may be the result of induction from the line.

Tracing Conductor by Use of Test Set I-51

If there is too much disturbance from the power line, or if the tone volume is inadequate, the stray current method will not be effective. Under such conditions the locating and tracing of a cable can generally be facilitated by using Test Set I-51 as a source of tracing current. The test set is placed as far as possible from the conductor at the point of tracing. The set may then be connected in any one of three ways, depending on the distance to be covered and the accessibility of the conductor to be located. Regardless of the method of construction, intermittent tone should be used in the set.

When the conductor to be traced is relatively short and is accessible at two points, as is shown in figures 4-33 and 4-34 (one on each side of the area in question), it is advisable to connect the set directly. The connection is made with insulated wires which are attached to terminals 3 and 5 of the set, and are placed on the ground in such a way that they will not parallel the conductor in the area where the location is made. Intermittent tone should be used.

When the conductor to be traced is accessible at one point and the approximate location is known at another point, the tracing current can be applied as illustrated in figure 4-35. Install the ground rod 5 to 20 feet from the

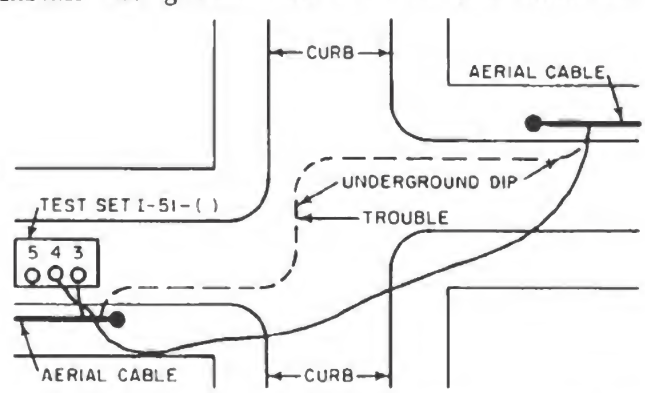
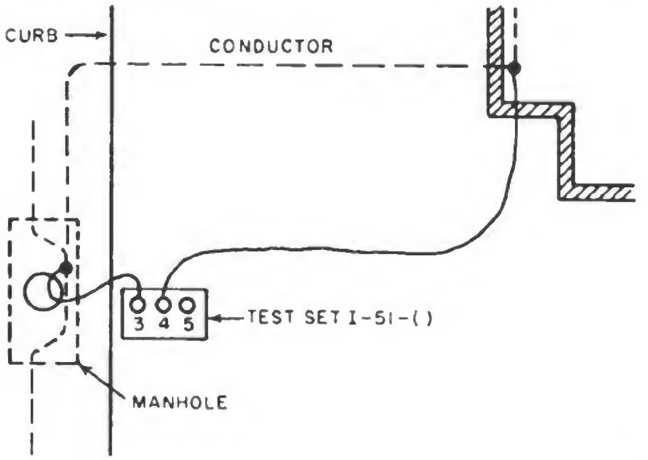
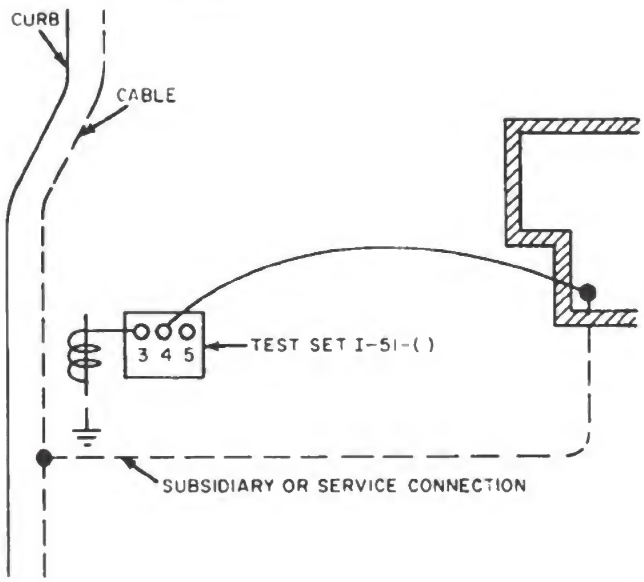


Figure 4-33.—Tracing buried cable conductor with test set I-51, underground dip.



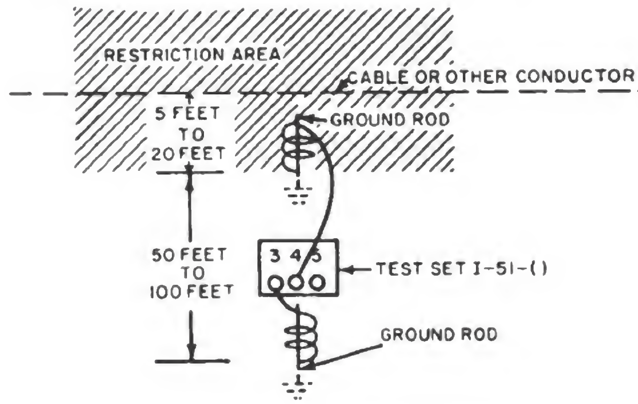
26.59
Figure 4-34.—Tracing cable conductor in underground subsidiary with test set I-51.



26.60
Figure 4-35.—Tracing accessible conductor with test set I-51, and one ground rod.

cable. Connect the set to the conductor and rod as described above, except that a number 3 bridging connector may be used to attach the lead to the rod.

If the conductor to be traced is not accessible and the approximate location is known, install one ground rod close to the conductor (5 to 20 feet), and another ground about 50 feet from the first ground rod and in a line approximately at right angles to the conductor (fig. 4-36). If the approximate location of the conductor is not



26.61
Figure 4-36.—Tracing inaccessible conductor with test set I-51, and two ground rods.

known, the separation between the rods should be about 100 feet. If a power line is in the vicinity of the conductor, place the rods on the power-line side of the conductor. Drive the rods approximately 2 1/2 feet into the earth; but where the soil is loosely packed or contains many small stones, drive the rods deeper, or move them to another location where the soil conditions are more favorable. If the separation between rods is not over 50 feet, make location tests at a point not less than 100 feet from the rods. Within this area a strong tone will be heard, but the location will not be reliable. Where the separation is more than 50 feet, the restricted area extends about 200 feet from the conductors.

Locating Conductors

To locate conductors stand at a point that is believed to be near the cable or conductor (on the side away from any power line, if there is one nearby). Hold the exploring coil in a horizontal position and rock it slowly around a horizontal axis which is considered parallel to the conductor, as shown in figure 4-37.

When maximum tone is heard in the receivers, the plane of the coil is at right angles to this position. A further check on the location can be made by holding the exploring coil in a vertical position and then rotating the coil around its vertical axis. When the tone in the receivers is at a minimum, the plane of the coil is perpendicular to the conductor. When the tone is at a maximum, the plane of the coil is parallel to the conductor. If no definite

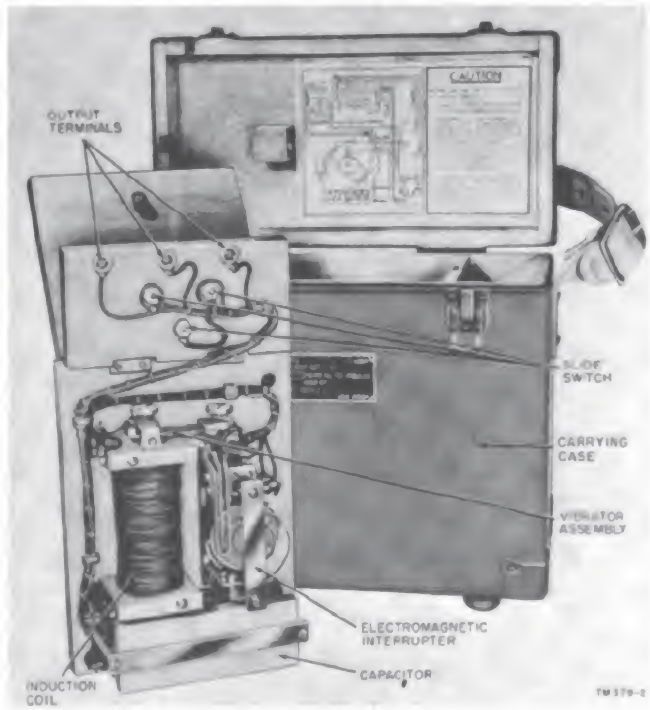
26.62
Figure 4-37.—Getting general location of buried cable.

maximum or minimum tone position can be found, the tests are repeated at other points in the general vicinity.

After the general location of the conductor has been determined, the following procedure will be followed to find the exact location. Starting at the point where the approximate locations were made and with the coil in a horizontal position, walk toward the conductor. The tone volume will rise gradually to a maximum as the conductor is approached, suddenly fall to a low value when the coil is directly over the conductor, rise again to the previous maximum as the conductor is passed, and then decrease slowly. If a check test is desired, hold the coil in a vertical position, with the plane of the coil parallel to the conductor, and again walk across the conductor. The tone volume will rise as the conductor is approached, reach a maximum directly over the conductor, and then decrease as the conductor is passed.

PREVENTIVE MAINTENANCE

The most important preventive maintenance techniques to be applied to the cable repairman's test set I-51 are the visual inspection and cleaning. To perform the maintenance operations listed below, it will be necessary to remove the tone unit from the carrying case (fig. 4-38). Lift the battery case cover and the cover on which the tone switch is mounted and, using them as a handle, lift the tone unit straight up and out of the carrying case.



26.63
Figure 4-38.—Test set I-51, tone unit removed from carrying case.

INSPECTION

Perform the inspections and checks listed below. Repair all loose or broken connections discovered.

CAUTION: Tighten screws, bolts and nuts carefully. Fittings tightened beyond the pressure for which they are designed will be damaged or broken.

1. Check for completeness and general condition of the test set.
2. Check and tighten mounting screws on all components.
3. Inspect for loose or broken electrical connections; loose or broken parts; cut, frayed, or bare wires, cable, or webbing.

4. Check for accumulation of dust and dirt.
5. Inspect batteries for corrosion.
6. Check battery voltage.
7. Check for normal operation.

CLEANING

1. Clean the carrying case.
2. Clean the tone unit with a camel's-hair brush.
3. Thoroughly clean and polish the insulated areas between the line terminals on the set and between the receiver jacks on the exploring coil. Remove all traces of lint after cleaning.
4. Remove corrosion from battery terminals with a clean cloth.
5. Clean the receiver unit.

CHAPTER 5
POWER GENERATORS

As a Construction Electrician First Class or a Chief Construction Electrician, you may have the responsibility of supervising the installation, operation, maintenance, and repair of advanced-base type generating equipment. This equipment is portable and ranges in size from 1.5 kw to 600 kw. In time of war or national emergency portable generating equipment will normally be used at temporary overseas bases. Even in peacetime, portable equipment may be used at remote bases.

At larger, more permanent activities you may have duties associated with the installation of large electrical power systems. After the Korean Conflict, for example, Seabees erected a 69,000-volt, 400-ampere main line switching station with 60-foot towers and a master substation for the Marine Corps Air Facilities at Futema, Okinawa. The master substation at this facility also has 60-foot towers and contains a 5000-kva transformer and a metal-clad switch building. The switch building houses all automatic and manual controls and breakers for the distribution of power.

GENERATOR SELECTION

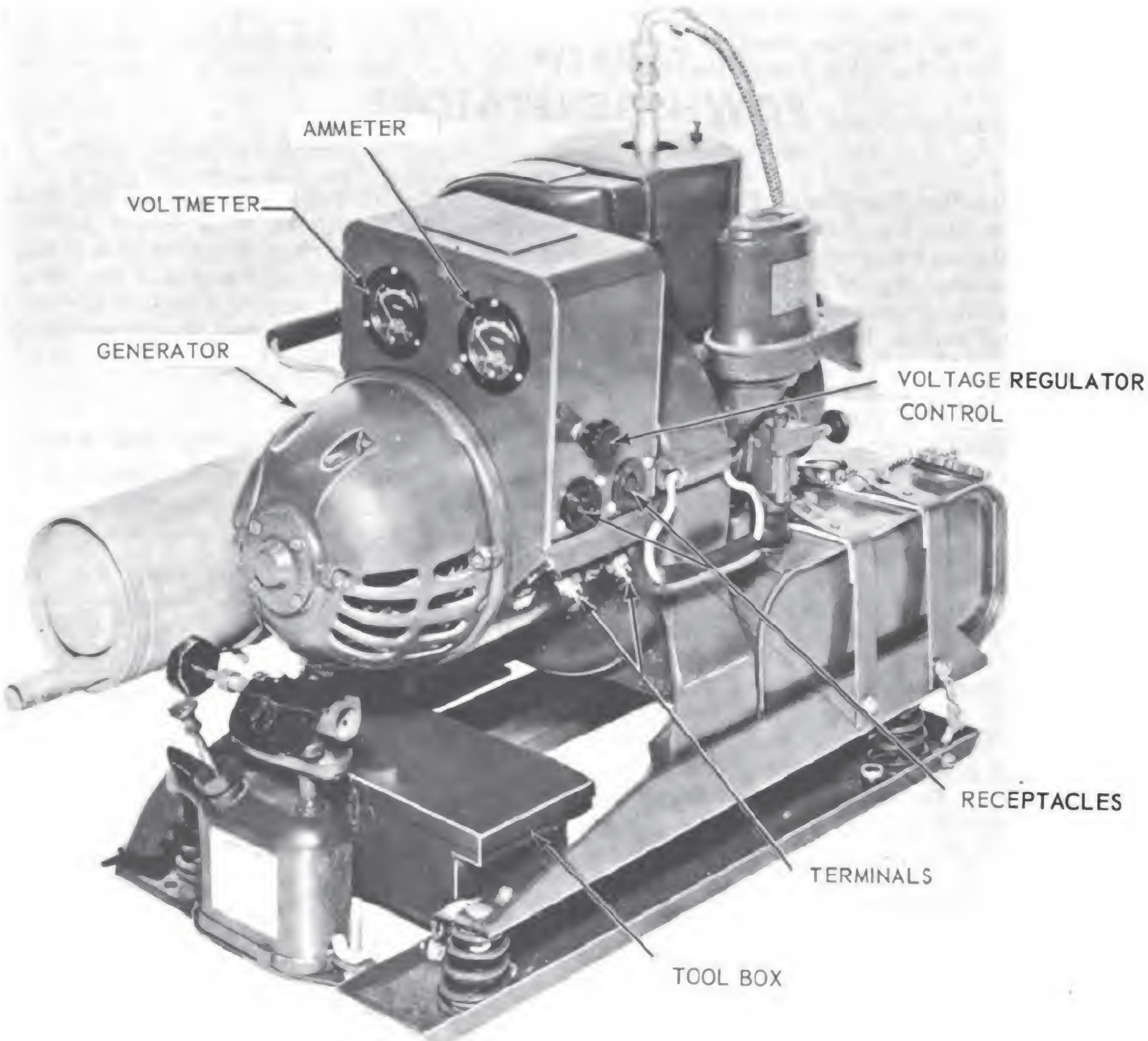
When an overseas base is first established, electric power is needed in a hurry; you will not have time to set up a centrally located generating station. Instead, you will spot a portable plant at each important location requiring power. Table 5-1 lists some of the standard alternating current generators available. One standard generator not listed in the table is the 600-kw generator which will be described in detail later in this chapter. These standard generators are capable of meeting the power requirements of advanced bases.

The 1.5 kw output generator delivers 120 volts single phase at a frequency of 60 cycles. It is a very versatile and widely used small generator because its output is adequate for the communications and lighting requirements for use in the field. Figure 5-1 shows a typical 1.5-kw generator mounted on a base with handles to make it transportable by two men. The simplicity of operation is evidenced by a single control, consisting of a field rheostat or voltage-regulator control to permit adjustment of the voltage and frequency of the output. A typical 10- and a typical 60-kw generator are illustrated in figures 5-2 and 5-3.

Table 5-1. Family of Engine-Generators.

	Alternating current					
Frequency	60-cycles					
Voltage	120		120/208		120/208 240/416	
Phase	1		1 & 3		3	
Wires	2		4*		4	
Fuel	G	D	G	D	G	D
KW Rating						
1.5	x					
3			x			
5			x			
10			x			
15					x†	x†
30					x†	x†
45						x†
60					x	x†
100						x†
150						x†

G—Gasoline driven. D—Diesel driven.
†—These generators to produce either 50- or 60-cycle current.
*—Panel connections permit, at rated KW output: 120/208v 3-phase 4-wire, 120v 3-phase 3-wire, 120v single phase 2-wire, 120/240v single phase 3-wire.



26.64

Figure 5-1.—Typical 1.5-kw, 120-volt, 60-cycle, portable generator set.

The electrical loads to be supplied, power, voltage, phase, and frequency requirements govern the selection of generating equipment. Probable load deviation, probable life of the installation, availability of fuels, and availability of skilled personnel are other important factors.

Electrical plants at advanced bases serve a varied load of lighting, heating, and power equipment, most of which demand power day and night. The annual load factor (the ratio of average power to peak power) of a well operated active base should be 50 percent or more with a power factor (explained later in the chapter) of 80 percent or higher. If the load is more than a few hundred feet from the power source, a high voltage distribution system is required.

If several generators are to serve primary distribution systems, they should generate the same voltage to avoid need for voltage transformation. The number of phases required by the load may differ from that of the generator. As loads can usually be divided and balanced between

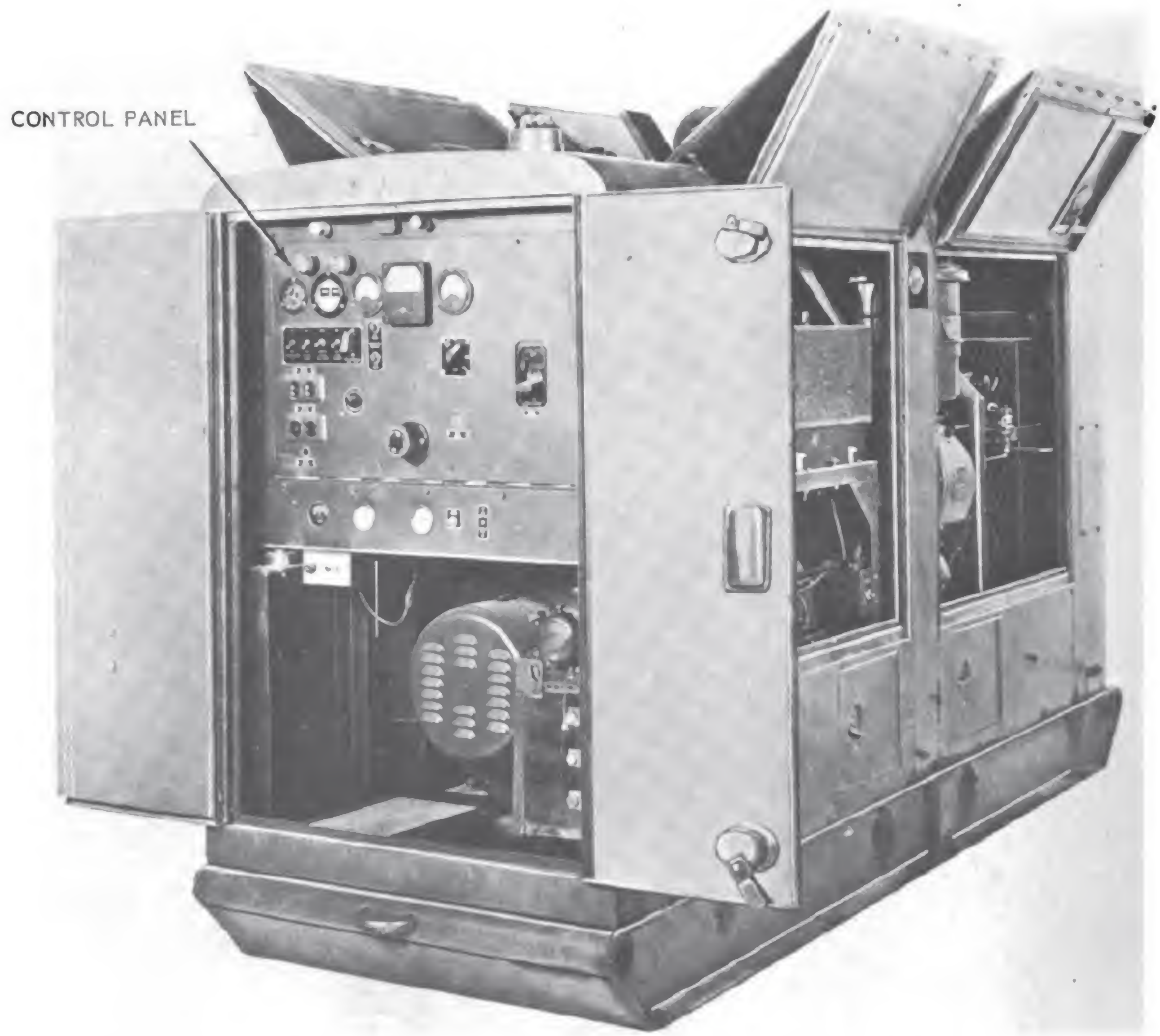
26.65

Figure 5-2.—Typical 10-kw, 120/208-volt 3-phase, 4-wire, 60-cycle portable generator set.

phases, most generators of appreciable sizes are wound for 3-phase operation.

POWER AND VOLTAGE REQUIREMENTS

The power and voltage requirements of the load will normally determine the size of the generator to be used. For example, electrical equipment rated at 120 volts, single phase with a combined power load of less than 1500 watts can be adequately handled by a gasoline or diesel-driven power plant with a 120-volt, 2-wire output rated at 1.5 kw. If the power demand of the equipment is greater than 1.5 kw, but does not exceed 4.5 kw, a generator rated at 5 kw,



26.66

Figure 5-3.—Typical 60-kw, 120/208- or 240/416-volt, 3-phase, 4-wire, 60-cycle diesel-driven generator set.

120 volts, with a 2-wire output can be used. However, if motors are included as part of the load, then the generator capacity must be increased above that which would normally be used. When starting a large motor, the reduction in terminal voltage, along with the frequency surges occurring during the motor accelerating period may affect the performance of electronic systems and other electrical equipment supplied from the same generator. Furthermore, other motors already running may stall because of this low transient terminal voltage. When a large motor is being started, part or all the existing load should be removed to avoid such conditions. These smaller loads may be put back on the generator after the large motor has come up to speed. If a single phase load contains equipment rated at both 115 and 230 volts, a 3-, 5-, or 10-kw diesel- or gasoline-driven generator with a 120/240-volt, single-phase, 3-wire

output can be used, depending on the load requirements.

The selection of voltage is affected by the size, character, and distribution of the load; length, capacity, and type of transmission and distribution circuits; and size, location and connection of generators. Practically all general purpose lighting in the United States and at United States overseas bases is 120 volts. The lighting voltage may be obtained from a 3-wire, 120/240-volt, single-phase circuit or a 120/208-volt, 3-phase, 4-wire circuit. Some small motors can be supplied by direct current or single phase alternating current at nominally 120 volts. Large 3-phase a-c motors, above 5 horsepower, will generally operate satisfactorily at any voltage between 200 and 240. The general use of combined light and power circuits increases the use of 240 or 208 volts for general power application.

COMPUTING THE LOAD

As mentioned earlier in this chapter there are various factors that must be taken into consideration in the selection of the required generating equipment. The following technical data will help you in computing the load.

Demand Factor

Demand factor is the ratio of the maximum LOAD DEMAND to the total connected load. CONNECTED LOAD is the sum of the rated capacities of all electrical appliances, lights, heaters, motors, and so on. The ACTUAL DEMAND is generally much less than the connected load because different pieces of apparatus are used at different times or because the peak loads of these various pieces are not usually simultaneous. An exception occurs where all utilization apparatus is of the same general type and used at the same time to full capacity such as shop or street lighting. For example, a repair shop may have a 31.4-kw maximum demand by actual measurement. The total connected load may be as follows:

Thirty 60-watt lamps	1.8-kw
Twenty 100-watt lamps	2.0-kw
Motors, total connected	30.0-kw
Welding equipment	20.0-kw
Heating apparatus	9.0-kw
Total connected load	62.8-kw

$$\text{Demand factor } \frac{\text{Maximum demand}}{\text{Total connected load}} \frac{31.4}{62.8}$$

0.5 or 50%

Diversity Factor

The diversity factor is the ratio of the sum of the maximum power demand of component parts of any system to the maximum demand of that system as a whole measured at the point of supply. For example, a generator may serve three different demand locations, each with a maximum demand of 30 kw, the maximum demand on the generator may be only 60 kw instead of 90 kw because the maximum demand of three locations do not occur simultaneously. This is illustrated in figure 5-4. Because the three loads A, B, and C vary in time, the generator at any one time need supply only the actual demand of the three loads, which in this case is 60. The diversity factor is:

$$\frac{90}{60} = 1.50$$

Power Factor

For a-c systems the power factor is defined as the ratio of the true power (watts) to the apparent power (volt-amps). True power is the actual power used in the load and may be measured by a wattmeter. The apparent power is the product of the voltage impressed on the load and the current flowing through the load.

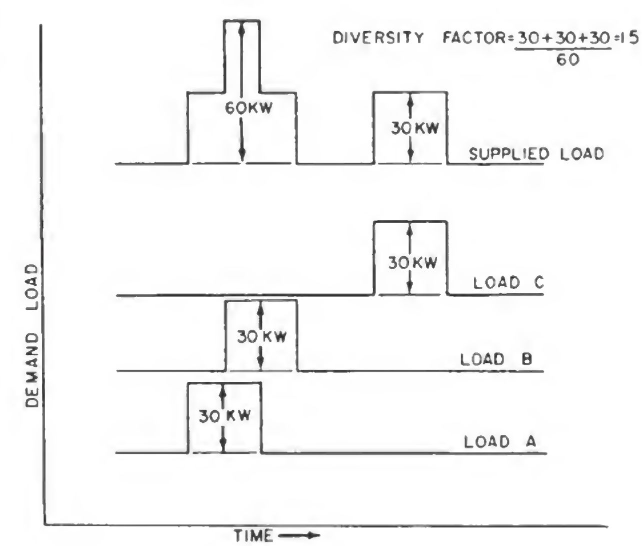


Figure 5-4.—Diversity factor.

Application of Demand and Diversity Factor

Application of demand and diversity factor in planning electrical facilities is a major consideration when requisitioning electrical generators. Knowing the demand factors for various types of buildings, equipment and installations is also beneficial when rearranging existing facilities because increased serving capacity is often not required, even though the connected load is greatly increased. Diversity factors of important loads must be considered when they contribute to the peak load. Some loads are at maximum demand at the same time as the peak load on the system; other loads occur at a time different from the peak and add little to the required capacity of the generator. For example, electrified mess hall adds only about 25 percent of its actual peak load to the system peak load.

SETTING UP THE GENERATOR

In setting up the generator first try to place the equipment near points of large demand, in order to reduce the size of wire required, to hold the line-losses to a minimum and to afford adequate voltage control at the remote ends of the lines. Generators must not be closer than 25 feet to a load, however.

If you are to select the site upon which the generator is to be set up, study a plot or chart of the area on which the individual buildings and facilities (demand) have been plotted. The site you select should be large enough to meet present and anticipated needs. It should be clear, level, dry, and well drained. If this type of site is not available, mount the generator set on a suitable foundation and bolt it down to eliminate any unnecessary vibration.

SHELTERING GENERATORS

Although advanced base portable generators are designed to be operated outdoors, prolonged exposure to wind, rain, and other adverse weather conditions will definitely shorten their life. If the generators are to remain on the site for any extended period of time, they should be mounted on solid concrete foundations and should be installed under some type of shelter.

There are no predrawn plans for shelters for a small advanced base generating station. The shelter will be an on-the-spot affair, the construction of which is determined by the equipment and material on hand plus your ingenuity, common sense, and your ability to cooperate with men in other ratings. Before a Builder can get started on the shelter, you will have to inform him of such things as the number of generators to be sheltered; the dimensions of the generators; the method of running the generator load cables from the generator to the bus bar and from the bus bar to the feeder system outside the arrangement of the exhaust system.

Installation specifications necessary for shelter plans can be obtained from the manufacturer's instruction manual that accompanies each unit. The following hints and suggestions will also be helpful.

1. Ventilation is an important factor to consider when installing the units inside a building. Every internal combustion engine is a HEAT engine. And, although heat does the work, excess amounts of it must be removed if the engine is to function properly. This can be accomplished by setting the engine's radiator grill near an opening in the wall and providing another opening directly opposite the unit. In this manner, cool air can be drawn in and the hot air directed in a straight line outdoors. These openings can be shielded with adjustable louvers to prevent the entrance of rain or snow. In addition, when operating in extremely cold weather, the temperature in the room can be controlled by simply closing a portion of the discharge opening. Additional doors or windows should be provided in the shelter if the plants are installed in localities where the summer temperatures exceed 80°F at any time.

2. Working space is another consideration. Be sure to provide sufficient space around each unit for repairs or disassembly and for easy access to the generator control panels.

3. The carbon monoxide gas present in the exhaust of the engine is extremely poisonous and must not be allowed to collect in a closed room. Therefore means must be provided to discharge the engine's exhaust to the outdoors. This is done by extending the engine's exhaust pipe through the wall or roof of the building. Support the exhaust pipe and make certain that no obstruction or too many right angle bends are used. Also, whenever possible, arrange the exhaust system so that the piping slopes away from the engine. In this way, condensation will not drain back into the cylinders. If the exhaust pipe should have to be installed so that loops or traps are

necessary, a drain cock should be placed at the lowest point of the system. All joints must be perfectly tight, and where the exhaust pipe passes through the wall, care must be taken to prevent the discharged gas from returning along the outside of the pipe back into the building.

Once the generating units have been set in place and bolted down, Builders can proceed to erect the building, using the necessary information with which they have been provided.

POWER (GENERATING) PLANT

As mentioned earlier in this chapter, generators of the advanced base type range in size from 1.5 kw to 600 kw. In this chapter we shall describe the lightweight 600 kw generator.

There are two types of 600-kw portable diesel electric generating plants: the heavyweight and the lightweight. The heavyweight is a 50-ton, medium-speed (720 rpm) plant, and the lightweight is a 45,500-pound, high-speed (1200 rpm) plant.

The large, heavyweight slower speed generator is more costly to install but more economical to operate and maintain. It is generally installed in projects having a life expectancy of 5 or more years. The large high-speed lightweight generator is cheaper to install but is more expensive to operate and maintain. This generator is generally used for projects with a life expectancy of less than 5 years.

The lightweight 600-kw portable diesel generator (fig. 5-5) has an overall width of 115 inches; an overall height from the bottom of the foundation to the top of the weatherproof housing of 104 inches; and an overall length of 24 feet.

The plant contains all components and accessories necessary to make a continuously operating unit that is capable of operating for at least 2 hours at 10 percent overload.

MAIN POWER UNIT

The engine is a Sterling Viking, 8-cylinder, 8-inch bore, 9-inch stroke, 4-cycle, solid-injection, supercharged diesel engine, with 1000 brake horsepower (bhp) maximum at 1200 rpm. The supercharger is of the Elliot exhaust-driven type, located at the flywheel end of the engine. Air intake of the supercharger is provided with an oil-wetted impingement cleanable-type air cleaner and silencer. Due to limitation

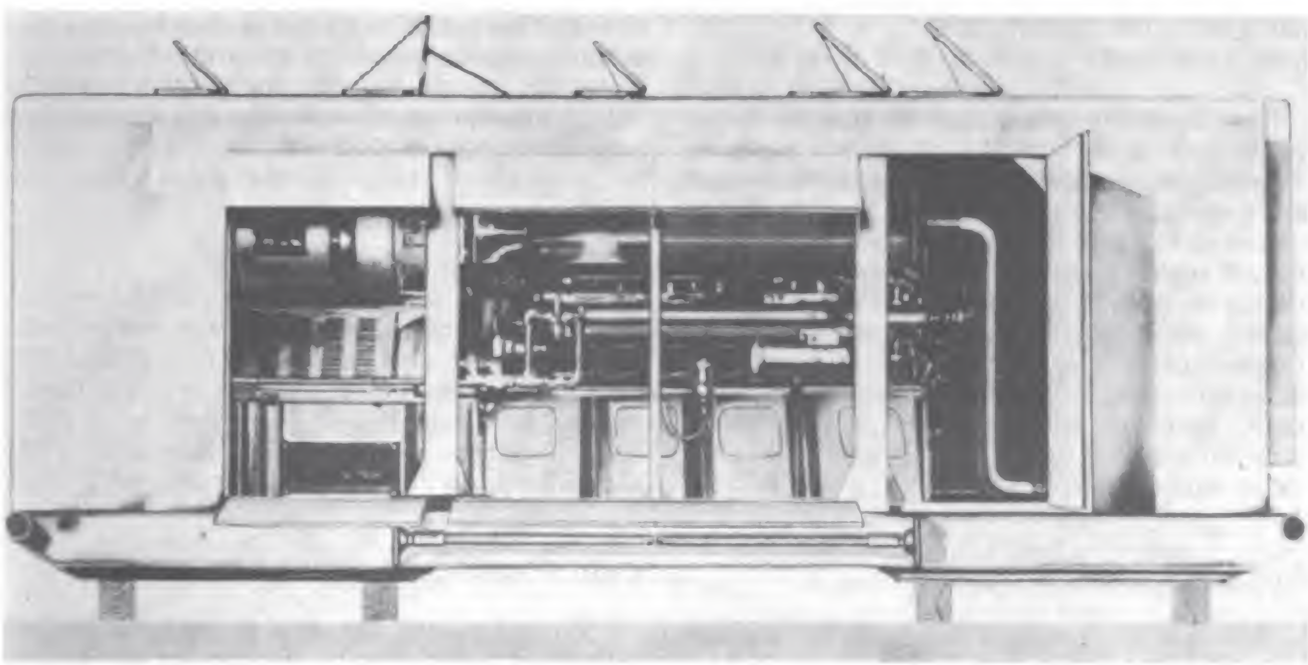


Figure 5-5.—600-kw portable power plant, lightweight highspeed type. 26.68

of space, all parts of the engine requiring removal are of a size and weight that permit removal by hand, without the use of hoists or other type of lifting gear. An electric motor driven air compressor, arranged with a heavy duty Bendix engagement to the flywheel ring gear, is provided for cranking the engine while starting. Starting-air supply to the air-operated motor is controlled by a 12-volt heavy-duty solenoid valve that is placed in operation by a spring loaded pushbutton switch on the engine control panel. Provisions are made for controlling the lubrication of the air-operated motor.

GENERATOR

The main generator will deliver 600 kw of 2400/4160 volts, 3-phase, 60-cycle alternating current to the bus at 0.8 power factor, exclusive of power consumed by accessories. The generator, is of a single-bearing construction with a forged flanged shaft, and is air cooled, drip proof, and self-ventilated; it operates at 1200 rpm, as mentioned previously. The exciter is directly connected to the free end of the main generator rotor. The generator set is designed to operate in parallel with other units of the same rating and manufacture.

AUXILIARY DIESEL ENGINE-GENERATOR SET

The auxiliary generator set has an output capacity of 6 kw of 120/208-volts, 3-phase, 60-cycle, 4-wire alternating current. The engine is a 4-cycle, solid injection diesel. This unit is connected to a bus in the main generator switchgear. It supplies current for all internal lighting, heating devices, battery charging rectifier, and motors required for the operation of the air compressor (for starting the main generator) and main engine lubricating oil filter circulating pump. Provisions are made to prevent interconnection of the auxiliary unit with main generator current supply or external power source.

STORAGE BATTERY

The unit is provided with a 12-volt storage battery capable of delivering 75 amperes for 6 hours or 450 ampere-hours. The battery supplies the direct current to the main engine speed-regulating governor motor, the emergency interior lighting system, the engine safety control operating devices, the auxiliary 6-kw generator starting motor, and to the main engine jacket fuel oil-fired water heater, fuel pump, and igniter. A selenium-rectifier type battery charger is provided, for operation on 120-volt, 60-cycle single-phase a-c and has a 12-volt d-c charging rate of 65 amp maximum with 18/25 amp minimum.

MAIN ENGINE JACKET WATER HEATER

A heater is located in the jacket cooling water system to provide heat to the main engine for cold weather conditions. The heater is operated by engine fuel oil and is capable of transmitting 60,000 btu per hour to the engine jacket water. The heater is equipped with various switches and controls for automatic operation.

UNIT HEATER

A unit type electric heater, with an air circulating fan, arranged for operation on 110-volt 60-cycle current having a capacity of 3000 watts is mounted in the end of the housing. This heater will circulate warm air when the plant is out of operation or in storage and will prevent interior condensation, or sweating. It is equipped with a wall-mounted thermostat having a temperature control of 40° to 80° F, supplied with a suitable ON-OFF switch.

AIR COMPRESSOR

The unit is equipped with an electric motor-driven, two-staged, aircooled air compressor having an actual capacity of 6.8 cfm at 250 psi to air start the main generator diesel engine. The compressor is driven by a 208-volt, 3-phase, 60-cycle splashproof electric motor having a capacity of 2 horsepower.

CABLE REEL AND CABLE

A cable reel mounted on bearings is located in front of the radiator to furnish storage of the necessary cables for connections between the main generator control switchgear terminals

and connected power source. The cable reel is of welded-tube construction to minimize restriction of air flow to the radiator.

The reel is furnished with one 50-ft length of number 4/0 extra-flexible, 3-conductor 5000 volt portable cable with ground wire for the main power supply. Suitable clamp-type terminals are furnished on each end of the cable. One 50-ft length of number 8 extra-flexible, 3-conductor 600-volt portable cable with ground wire is also provided for auxiliary purposes. This cable is equipped with a coupler plug at one end and a clamp-type terminal on the other. Two 25-ft lengths of number 2/0 extra-flexible portable cable, and number 2/0 600-volt neoprene-sheathed grounding conductors are provided with each plant.

MECHANICAL STRUCTURE OF THE 600-KW GENERATOR

The generator is equipped with a skid of welded steel construction, substantially ribbed and braced to a suitable base or foundation (see fig. 5-6). The unit has lifting pads installed for three point suspension. The skid is equipped with two tubular members which extend the full width of the base and are welded in a position to carry maximum weight for lifting the unit. The unit is equipped with four screw jacks that are constructed and mounted on tubular steel sections and arranged for insertion into the previously described tubular members welded into the base. The jacks can be locked in a vertical position when pulled out for lifting of the unit. Provision is also made for securing the lifting jacks when they are not in use and have been pushed back in horizontal position. Arrangement of the jacks will allow for lifting the entire unit 42 inches vertically, to provide necessary clearance for backing a trailer under the unit without any interference.

HOUSING

A weatherproof housing is provided and arranged to form a complete enclosure for all the equipment outlined in the preceding paragraphs, with exception of the outside face of the main generator cooling radiator. This housing is constructed of sheet aluminum, reinforced with bracing members on the roof, side and corner sections. Various components of the housing are joined together by spot welds and rivets. A hinged cover section is provided at the top of the main engine cooling radiator for filling. Eight hatch covers, with hinges and locking devices for open or closed position, are provided on the housing roof for ventilation. All openings except the main entrance door, which is equipped with lock and key, are provided with locking latches operable only from the inside of the housing. The main entrance door is provided with a folding platform and adjustable ladder which can be folded and stored when the unit is not in use or being transported.

INSPECTING THE GENERATOR AND SERVICING THE PRIME MOVER

After setting up a portable generator, your crew must do some preliminary work before

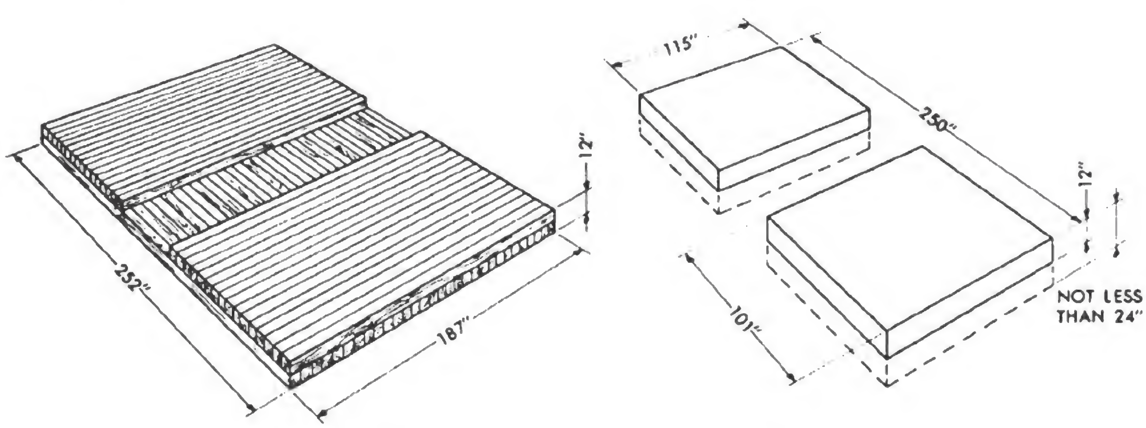


Figure 5-6.—Suggested foundation. 26.69

placing the generator in operation. First they should make a visual overall inspection of the generator particularly the alignment. Have them look for broken or loose electrical and hose connections, loose bolts and capscrews and see that the ground plate is properly grounded. If any wire connection is suspected of being improperly connected, check it against the wiring diagrams in the instruction manual furnished with the generator. Any faults that are found should be corrected immediately.

Servicing the prime mover is the next step in the process of placing the generator in operation. Be sure that the crankcase is filled with the proper grade of oil and lubricant. A lubrication chart in the instruction manual furnished with each generator will show the proper grade of oil to use in accordance with the operating temperature. If the plant is to be operated in freezing temperatures be sure the men use an antifreeze solution in the proportions recommended in the generator's instruction manual.

The fuel tank should be filled with clean fuel oil. The fuel should be strained if necessary.

Some of the prime movers of advanced base electric power generators are started by starting units which obtain their power from batteries. If the prime mover that you are installing is equipped with a battery (or batteries) your crew has another servicing job to do. Batteries are usually shipped without the electrolyte, but with the plates in a dry-charged condition. Thus, it is necessary to fill the battery with electrolyte. Usually, the electrolyte is shipped right with the generator and is of the correct specific gravity. However, if you must prepare your own electrolyte use the mixing chart in table 5-2.

Because specific gravity of the electrolyte depends on the type of battery furnished with the generator, use the specific gravity value as recommended by the manufacturer's instruction manual. Generally, you will find that batteries with wood separators require an electrolyte with a specific gravity of 1.255 and batteries with rubber separators a specific gravity of 1.200.

After the electrolyte has been prepared, follow the manufacturer's instruction manual with regard to the recommended filling procedure. In the event the manual is not available, have your men use the following general procedure:

1. Add electrolyte to each of the battery's cells until the level of the electrolyte is visible in the filler neck or at least 3/8 inch above the separators. The temperature of the electrolyte when placed in the cells should be between 60° and 90° F. IT SHOULD NEVER EXCEED 90° F.

2. Chemical reaction resulting when filling the battery will cause the battery to heat. It may be cooled artificially (cooling fans) or allowed to stand at least 1 hour before placing it in service.

3. You will probably notice at the end of the cooling period that the level of the electrolyte has dropped. This is due to the electrolyte

Table 5-2.—Electrolyte Mixing Chart.

Specific gravity desired	Using 1.835 specific gravity acid		Using 1.400 specific gravity acid	
	Parts of water	Parts of acid	Parts of water	Parts of acid
1.400	3	2	....	....
1.345	2	1	1	7
1.300	5	2	2	5
1.290	8	3	9	20
1.275	11	4	11	20
1.250	13	4	3	4
1.225	11	3	1	1
1.200	13	3	13	10

soaking into the plates and separators. Before placing the battery in service restore the electrolyte to its proper level.

4. Any electrolyte spilled on the battery should be removed with a cloth dampened with a solution of bicarbonate of soda and water.

Although the battery can be placed in service 1 hour after filling it with electrolyte, it is a procedure that you should consider only in an emergency. If at all possible, the battery should be given an initial light charge. If the charging procedure is not covered in the manufacturer's instruction manual, use the following general procedure:

1. Charge the battery at a low rate (about 5 amperes) until the voltage and specific gravity, corrected to 80°F, remains-constant for at least 5 hours.

2. If the temperature of the electrolyte reaches 125° F, reduce the charging rate or stop the charge until the battery cools.

3. During charging replenish any water lost by evaporation.

After the battery has been charged, it is connected into the starting system of the prime mover as indicated by the wiring diagrams accompanying the generator.

On the 600-kw generator you should check the ventilation; the fan cover must be opened and latched in that position. There must be no cover or obstructions over the main diesel engine exhaust stacks, or over the radiator section. The bypass shutters or doors may be opened to shorten the warming up period, and roof hatches and side louvers MAY be opened for additional ventilation, if required.

ALTERNATOR INSPECTION AND SERVICING

Just as important as the preparation of the prime mover is the inspection and servicing of the alternator. Generally, you should have your men take the following steps:

1. Check all the electrical connections by referring to the generator's connection diagrams.

2. See that connections are tight.

3. See that the collector rings are clean and have a polished surface.

4. Check collector brushes to make sure they have no tendency to stick in the brush holders, that they are properly located, and that the pigtails will not interfere with the brush rigging.

5. Check the collector brush pressure to see if it agrees with the figure recommended in the manufacturer's instruction manual. When the brush pressure information is not available, use a brush pressure of approximately 2 psi of brush area.

6. Check the exciter in the same manner as the alternator.

ELECTRICAL CONNECTIONS

While the electric generator is being installed and serviced, a part of your crew can connect it to the load. Essentially, this consists of running wire or cable from the generator to the load. At the load end, the cable is connected to the equipment or to the interior wiring system of the building. At the generator end, the cable is connected either to the output terminals of a main circuit breaker or a branch circuit breaker. When the wire is run and connections are made it will be up to you to:

1. Decide whether the wire or cable will be buried or carried overhead on poles.

2. Determine the correct size of wire or cable to use.

3. Check the generator lead connections of the plant to see that they are arranged for the proper voltage output.

The information contained in the following sections will help you in these tasks.

Installing the Load Cable

The load cable may be installed overhead or underground. In an emergency installation, time is the important factor. It may be necessary to use trees, pilings, four-by-fours or other temporary line supports to complete the installation. Such measures are temporary; eventually, you will have to erect poles and string the wire on crossarms or bury it underground. If the installation is near an airfield, it may be necessary to place the wires underground at the beginning. Wire placed underground should be rubber insulated, rubber jacketed cable; otherwise, it will not last long.

Direct burying of cable for permanent installation calls for a few simple precautions to ensure uninterrupted service. They are:

1. Dig the trench deep enough so that the cable can be buried at least 18 inches (24 inches in traffic areas and under roadways) below

the surface of the ground to prevent disturbance of cable by frost or subsequent surface digging (fig. 5-7).

2. Lay the cable over a sand cushion (fig. 5-7). If this is impractical, loosen the trench base so it is cleared of rocks and stones.

3. Space the cables on 6-inch centers for further mechanical and electrical protection (fig. 5-7).

4. After laying the cable and before backfilling, cover it with earth free from stones, rocks etc. This will prevent the cable from being damaged in the event the surrounding earth is disturbed by flooding or frost-heaving.

Determining Cable Size

If the wrong size conductor is used in the load cable, various troubles may occur. If the conductor is too small to carry the current demanded by the load, it will heat up and possibly cause a break in the circuit. A fire might result from this excess heat or break in the circuit. Even though the conductor is large enough to safely carry the load current, its length might result in a lumped resistance that produces an excessive voltage drop. An excessive voltage drop results in a reduced voltage at the load end that is incapable of operating the equipment. In this respect it might be well to point out that voltage drop should not exceed 3 percent for power loads and 1 percent for lighting loads or combined power and lighting loads. For example, if a generator generates 440 volts for power equipment, the voltage drop in the line should not exceed 13.2 volts (440 x 0.03).

To determine size, then, you must consider (1) the load current to be carried by the cable, and (2) the distance between the load and the generator. Generally, the following steps shown in tables 5-3 and 5-4 are involved:

Step 1. Compute the total current demand with the aid of tables 5-3 and 5-4.

Step 2. Use table 5-5 to find the size cable capable of carrying this total current.

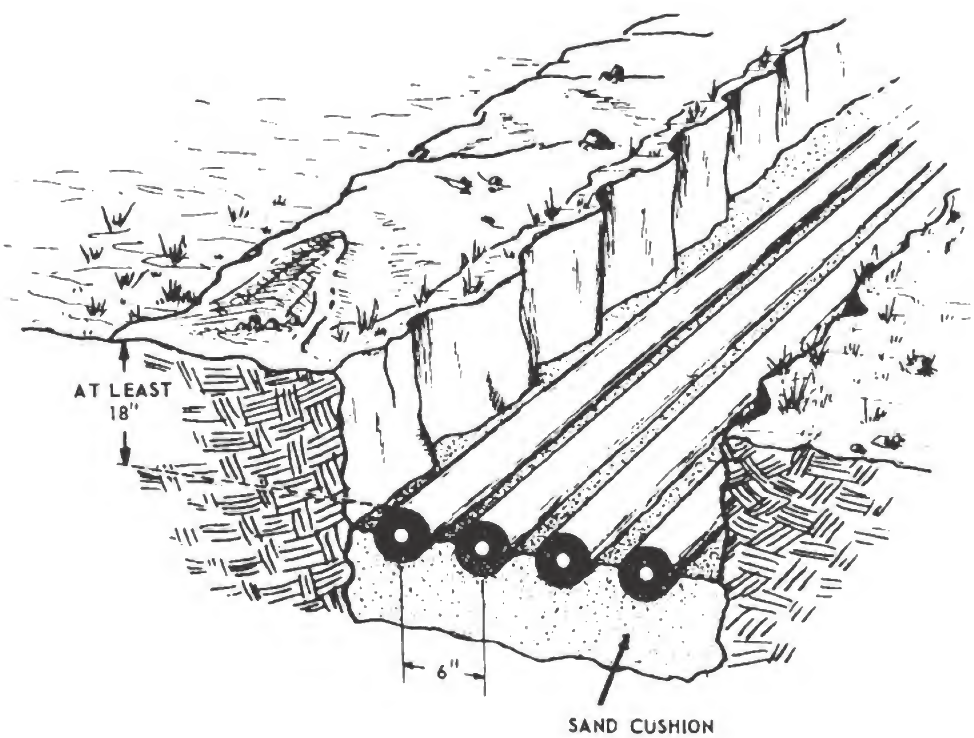


Figure 5-7.—Direct burial of cable showing proper cable spacing and depth. 26.70

Table 5-3. —Conversion Formulas.

To find—	Direct current	Alternating current	
		Single-phase	† Three-phase
Amperes when horsepower (input) is known	$\frac{\text{H. P. x 746}}{\text{Volts x effcy. (\%)}}$	$\frac{\text{H. P. x 746}}{\text{Volts x effcy. (\%) x P. F.}}$	$\frac{\text{H. P. x 746}}{\text{Volts x 1.73 x effcy. (\%) x P. F.}}$
Amperes when kilowatts is known	$\frac{\text{Kw. x 1,000}}{\text{Volts}}$	$\frac{\text{Kw. x 1,000}}{\text{Volts x P. F.}}$	$\frac{\text{Kw. x 1,000}}{\text{Volts x 1.73 x P. F.}}$
Amperes when Kv.-a. is known		$\frac{\text{Kv.-a. x 1,000}}{\text{Volts}}$	$\frac{\text{Kv.-a. x 1,000}}{\text{Volts x 1.73}}$
Kilowatts	$\frac{\text{Amperes x volts}}{\text{1,000}}$	$\frac{\text{Amps. x volts x P. F.}}{\text{1,000}}$	$\frac{\text{Amps. x volts x 1.73 x P. F.}}{\text{1,000}}$
Kv.-a		$\frac{\text{Amps. x volts}}{\text{1,000}}$	$\frac{\text{Amps. x volts x 1.73}}{\text{1,000}}$
Power factor	(P. F.)	$\frac{\text{Kilowatts}}{\text{Amps. x volts} \div \text{1,000}}$ or $\frac{\text{Kilowatts}}{\text{Kv.-a.}}$	$\frac{\text{Kilowatts}}{\text{Amps. x volts x 1.73} \div \text{1,000}}$ or $\frac{\text{Kilowatts}}{\text{Kv.-a.}}$
Horsepower (output)	$\frac{\text{Amps. x volts x effcy. (\%)}}{\text{746}}$	$\frac{\text{Amps. x volts x effcy. (\%) x P. F.}}{\text{746}}$	$\frac{\text{Amps. x volts x 1.73 x effcy. (\%) x P. F.}}{\text{746}}$

Power factor (P. F.) as used in formulas is expressed as a decimal except in the case of unity power factor which is expressed as 1.0.

† For 2-phase, 4-wire substitute 2 instead of 1.73.

† For 2-phase, 3-wire substitute 1.41 instead of 1.73.

Table 5-4.—Full-load Currents of Motors.

The following data are approximate full-load currents for motors of various types, frequencies, and speeds. They have been compiled from average values for representative motors of their respective classes. Variations of 10 percent above or below the values given may be expected.

Amperes — Full-load current

Hp. of motor	Direct-Current motors			Alternating-Current motors: Single-phase motors		Squirrel-cage induction motors: Two-phase					Squirrel-cage induction motors: Three-phase				
	115-volt	230-volt	550-volt	110-volt	220-volt	110-volt	220-volt	440-volt	550-volt	2,200-volt	110-volt	220-volt	440-volt	550-volt	2,200-volt
1/4	----	----	----	4.8	2.4	----	----	----	----	----	----	----	----	----	----
1/2	4.5	2.3	----	7	3.5	4.3	2.2	1.1	0.9	----	5.0	2.5	1.3	1.0	----
3/4	6.5	3.3	1.4	9.4	4.7	4.7	2.4	1.2	1.0	----	5.4	2.8	1.4	1.1	----
1	8.4	4.2	1.7	11	5.5	5.7	2.9	1.4	1.2	----	6.6	3.3	1.7	1.3	----
1-1/2	12.5	6.3	2.6	15.2	7.6	7.7	4.0	2	1.6	----	9.4	4.7	2.4	2.0	----
2	16.1	8.3	3.4	20	10	10.4	5	3	2.0	----	12.0	6	3.0	2.4	----
3	23	12.3	5.0	28	14	----	8	4	3.0	----	----	9	4.5	4.0	----
5	40	19.8	8.2	46	23	----	13	7	6	----	----	15	7.5	6.0	----
7-1/2	58	28.7	12	68	34	----	19	9	7	----	----	22	11	9.0	----
10	75	38	16	86	43	----	24	12	10	----	----	27	14	11	----
15	112	56	23	----	----	----	33	16	13	----	----	38	19	15	----
20	140	74	30	----	----	----	45	23	19	----	----	52	26	21	5.7
25	185	92	38	----	----	----	55	28	22	6	----	64	32	26	7
30	220	110	45	----	----	----	67	34	27	7	----	77	39	31	8
40	294	146	61	----	----	----	88	44	35	9	----	101	51	40	10
50	364	180	75	----	----	----	108	54	43	11	----	125	63	50	13
60	436	215	90	----	----	----	129	65	52	13	----	149	75	60	15
75	540	268	111	----	----	----	156	78	62	16	----	180	90	72	19
100	----	357	146	----	----	----	212	106	85	22	----	246	123	98	25
125	----	443	184	----	----	----	268	134	108	27	----	310	155	124	32
150	----	----	220	----	----	----	311	155	124	31	----	360	180	144	36
175	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
200	----	----	295	----	----	----	415	208	166	43	----	480	240	195	49

Hp. of motor	Slip-ring induction motors: Two-phase					Slip-ring induction motors: Three-phase				
	110-volt	220-volt	440-volt	550-volt	2,200-volt	110-volt	220-volt	440-volt	550-volt	2,200-volt
1/4	----	----	----	----	----	----	----	----	----	----
1/2	----	----	----	----	----	----	----	----	----	----
3/4	6.2	3.1	1.6	1.3	----	7.2	3.6	1.8	1.5	----
1	6.7	3.4	1.7	1.4	----	7.8	3.9	2.0	1.6	----
1-1/2	11.7	5.9	3.0	2.3	----	----	----	----	----	----
2	12.5	6.3	3.1	2.5	----	14.4	7.2	3.6	2.9	----
3	----	8.7	4.3	3.5	----	20.2	10	5.0	4	----
5	----	13.0	6.5	5.2	----	----	15	7.5	6	----
7-1/2	----	20.0	10.0	7.6	----	----	25	13	10	----
10	----	24.3	12.1	10.0	----	----	28	14	11	----
15	----	39	19.5	15.6	----	----	45	23	18	----
20	----	49	24.7	19.8	----	----	56	28	22	----
25	----	60	30.0	24.0	6.4	----	67	34	27	7.5
30	----	72	36.0	28.8	7.8	----	82	41	33	9
40	----	93	46.5	37.3	9.5	----	106	53	42	11
50	----	113	57	45	12.1	----	128	64	51	14
60	----	135	68	54	14.0	----	150	75	60	16
75	----	164	82	65	17.3	----	188	94	75	19
100	----	214	108	87	21.7	----	246	123	99	25
125	----	267	134	108	27	----	310	155	124	31
150	----	315	158	127	32	----	364	182	145	37
175	----	----	----	----	----	----	----	----	----	----
200	----	430	216	173	44	----	490	245	196	52

Table 5-5.—Allowable Current-Carrying Capacities of Conductors in Amperes.

Not More Than Three Conductors in Raceway or Cable (Based on Room Temperature at 30 C. (86 F.)

Size AWG or MCM	B	C	D	E	F	G
	Rubber Type R type RW type RU (14-6) / Thermo-plastic type T (14-4/0) type TW (14-4/0)	Rubber Type RH	Paper / Thermo-plastic asbestos type TA / Var-cam type V / Asbestos var-cam type AVB	Asbestos var-cam type AVA type AVL	Impreg-nated asbestos type AI (14-8) type AIA	Asbestos type A (14-8) type AA
14	15	15	25	30	30	30
12	20	20	30	35	40	40
10	30	30	40	45	50	55
8	40	45	50	60	65	70
6	55	65	70	80	85	95
4	70	85	90	105	115	120
3	80	100	105	120	130	145
2	95	115	120	135	145	165
1	110	130	140	160	170	190
0	125	150	155	190	200	225
00	145	175	185	215	230	250
000	165	200	210	245	265	285
0000	195	230	235	275	310	340
250	215	255	270	315	335	---
300	240	285	300	345	380	---
350	260	310	325	390	420	---
400	280	335	360	420	450	---
500	320	380	405	470	500	---
600	355	420	455	525	545	---
700	385	460	490	560	600	---
750	400	475	500	580	620	---
800	410	490	515	600	640	---
900	435	520	555			
1,000	455	545	585	680	730	---
1,250	495	590	645	---	---	---
1,500	520	625	700	785	---	---
1,750	545	650	735	---	---	---
2,000	560	665	775	840	---	---

Correction factor for room temperatures over 30 C. (86 F.)

°C.	°F	B	C	D	E	F	G
40	104	0.82	0.88	0.90	0.94	0.95	---
45	113	.71	.82	.85	.90	.92	---
50	122	.58	.75	.80	.87	.89	---
55	131	.41	.67	.74	.83	.86	---
60	140	---	.58	.67	.79	.83	0.91
70	158	---	.35	.52	.71	.76	.87
75	167	---	---	.43	.66	.72	.86
80	176	---	---	.30	.61	.69	.84
90	194	---	---	---	.50	.61	.80
100	212	---	---	---	---	.51	.77
120	248	---	---	---	---	---	.69
140	284	---	---	---	---	---	.59

Step 3. Use table 5-6 to determine what the lumped resistance of the cable will be when stretched between the generator and the load.

Step 4. Compute the voltage drop in the cable with the information obtained in step 3.

Step 5. Compare this voltage drop to the maximum figure allowed; that is, 3 percent for power load and 1 percent for lighting load or light and power combined.

Perhaps an example will help. A rough sketch of a typical emergency installation is shown in figure 5-8. A 30-kw, diesel-engine driven generator is supplying on the spot power to electrical equipment located 50 feet away. The voltage output of the generator is 127/220 volts and is to be carried over to the equipment via four single-conductor rubber-jacket cables.

The first step is to complete the total load current. This will be the sum of the current required by the individual pieces of electrical equipment. In this particular example you find the following:

12 100-watt, 120-volt lamps.

1 10-horsepower, 220-volt, 3-phase, slip-ring induction motor.

Twelve 100-watt lamps require a total power input of 1200 watts or 1.2 kw. (12 x 100 watts). Table 5-3 indicates that to find amperes when kilowatts are known for single phase a-c circuits the following formula should be used:

$$I=\frac{\text{kw.} \times 1000}{\text{volts} \times \text{power factor}}$$ (P.F. for lighting circuits is 1).

Therefore, by substitution

$$I=\frac{1.2 \times 1000}{120 \times 1} = 10 \text{ amperes for the lamps.}$$

This takes care of the lighting load. Now figure the current required by the motor. Table 5-4 shows that a 10-horsepower, 220-volt, 3-phase, induction motor has a full-load current of 28 amperes.

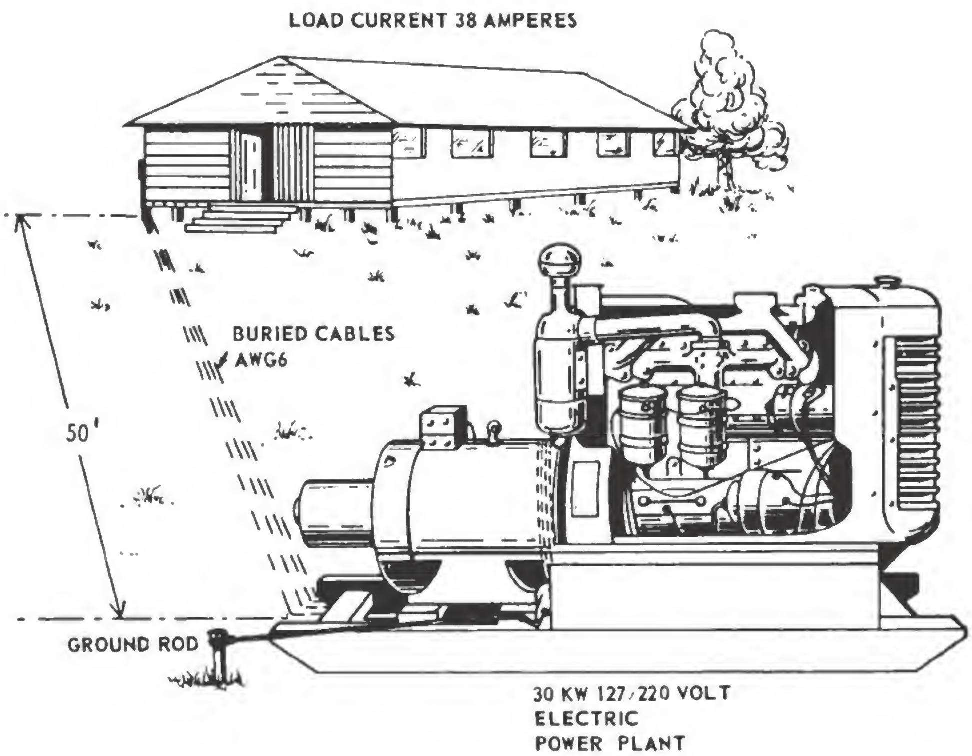


Figure 5-8.—Determining wire size.

26.71

Table 5-6.—Physical Properties of Conductors.

Standard stranded conductor		I. P. C. E. A. class B	Resistance ohms 1,000 ft. at 25°C. (77° F.)	
Size AWG	Circular mils	Number of wires	Bare copper	Tinned copper
18	1,624	7	6.64	7.05
16	2,583	7	4.18	4.43
14	4,107	7	2.63	2.69
12	6,530	7	1.65	1.72
10	10,380	7	1.04	1.08
9	13,090	7	0.824	0.856
8	16,510	7	0.654	0.679
7	20,820	7	0.519	0.538
6	26,250	7	0.410	0.427
5	33,100	7	0.326	0.339
4	41,740	7	0.259	0.269
3	52,640	7	0.205	0.213
2	66,370	7	0.162	0.169
1	83,690	19	0.129	0.134
1/0	105,500	19	0.102	0.106
2/0	133,100	19	0.0811	0.0842
3/0	167,800	19	0.0642	0.0668
4/0	211,600	19	0.0509	0.0525
---	250,000	37	0.0431	0.0449
---	300,000	37	0.0360	0.0374
---	350,000	37	0.0308	0.0320
---	400,000	37	0.0270	0.0278
---	450,000	37	0.0240	0.0247
---	500,000	37	0.0216	0.0222
---	550,000	61	0.0196	0.0204
---	600,000	61	0.0180	0.0187
---	650,000	61	0.0166	0.0171
---	700,000	61	0.0154	0.0159
---	750,000	61	0.0144	0.0148
---	800,000	61	0.0135	0.0139
---	900,000	61	0.0120	0.0123
---	1,000,000	61	0.0108	0.0111
---	1,250,000	91	0.00863	0.00888
---	1,500,000	91	0.00719	0.00740
---	1,750,000	127	1.00616	0.00634
---	2,000,000	127	0.00539	0.00555

Summing up the individual current demands of the equipment you have:

12 100-watt lamps . . . . 10 amps

1 10-horsepower 220-volt 3-phase slip-ring induction motor . . . 28 amps

Total load current = 38 amps

The second step is to choose the cable capable of carrying 38 amperes. Table 5-5 will help you. It lists the allowable current-carrying capacities of conductors of different sizes with different insulation coverings. You are installing underground cable that has a moisture-resistant rubber covering, type RW. Therefore you will use column B of the table. Follow column B down until you reach an ampere value

that is greater than 38 amperes. In this case you find a value of 40 amperes. However, since 38 amperes is so close to 40 amperes you should choose the next ampere value (55) to allow for possible additions to the load. Column A indicates that conductor size AWG No. 6 is capable of carrying 55 amperes.

Step three is to find the amount of resistance that the load current will meet if you used No. 6 cable. Table 5-6 lists the physical properties of stranded conductors. It shows that a No. 6 tinned copper conductor possesses 0.427 ohms of resistance in every 1000 feet. The cable is to run a distance of 50 feet between the plant and the load. However, since the current must travel both ways it will actually pass through 100 feet of cable. Therefore, the total amount of resistance it will meet will be:

$$R= \frac{0.427 \times 100}{1000} =0.0427 \text{ ohms.}$$

In step four you are to find the voltage drop in the cable. All it takes is a simple application of Ohm's law.

$$E \text{ (voltage)} = I \text{ (load current)} \times R \text{ (cable resistance)}$$

$$\text{or } E = 38 \times 0.0427 = 1.62 \text{ volts}$$

In step five you compare the actual voltage drop that will occur in the cable with the value allowed. The voltage drop in the cable (step 4) is 1.62 volts. The maximum voltage drop allowed for a combined lighting and power circuit is 1 percent of the source voltage. In this case the power plant generates 220 volts. Therefore the voltage drop should not exceed 2.2 volts (220 x 0.01). You can see that the actual voltage drop (1.62 volts) is well within this limit, so you can use a AWG No. 6 cable and meet all requirements. If the actual voltage drop had been greater than the allowable value it would be necessary to use the next larger size cable.

Generator Connections

When you install a power plant that has a dual-voltage alternator unit, you must make certain that the armature coil leads are properly connected to produce the voltage required by the equipment. Take a look at figure 5-9. It shows an alternator unit that has been disconnected and removed from a three-phase diesel driven power plant. Plainly visible are the stationary armature coils and core (stator) mounted in the main frame of the generator. The a-c voltages generated in the coils are brought through an opening in the pedestal of the frame by means of 10 coil leads. Each coil lead is identified by a number stamped on a metal band.

In 220/440-volt dual-voltage, three-phase generators the voltage generated in each set of coils, when the prime mover is operating at rated speed, is 127 volts. Thus, by connecting the external coil leads together in different combinations, you can change the external voltage output of the generator. The chart in table 5-7 gives the exact data needed to make these connections for both three-phase and single-phase voltage outputs.

Let's take a specific example. Suppose it becomes necessary to obtain 220-volts single-phase from a three-phase, dual-voltage generator. Checking table 5-7 you find that coil leads T2 and T8 are to be connected together and then in turn, connected, through the main circuit breaker, to one of the two load cables. Similarly coil leads T3 and T9 are to be secured and connected, through the main circuit breaker, to the other load cable. Terminal lugs on the end of each coil lead provide an easy means of bolting them together. Just be sure that the connections are thoroughly insulated with a wrapping of rubber tape followed by a wrapping of friction tape. Table 5-7 indicates that leads T1, T4, T7, and T0 are not used for single-phase service. Therefore, to finish the job, you should individually insulate each of these four leads with rubber and friction tape. Figure 5-10(a) shows you how the connections appear on the stator coil diagram. Figure 5-10(b) shows the appearance of the actual connections.

RECONNECTING GENERATOR LEADS

When you reconnect generator leads to meet certain load conditions, you change not only the voltage output of the generator but also its current rating. These voltage and current changes will have an effect on the operational characteristics of the switchboard controls and instruments. Thus, before the generator can be put into operation, certain internal alterations must be affected.

For example, suppose that it becomes necessary to reconnect a 75-kw., 3-phase, 220-volt

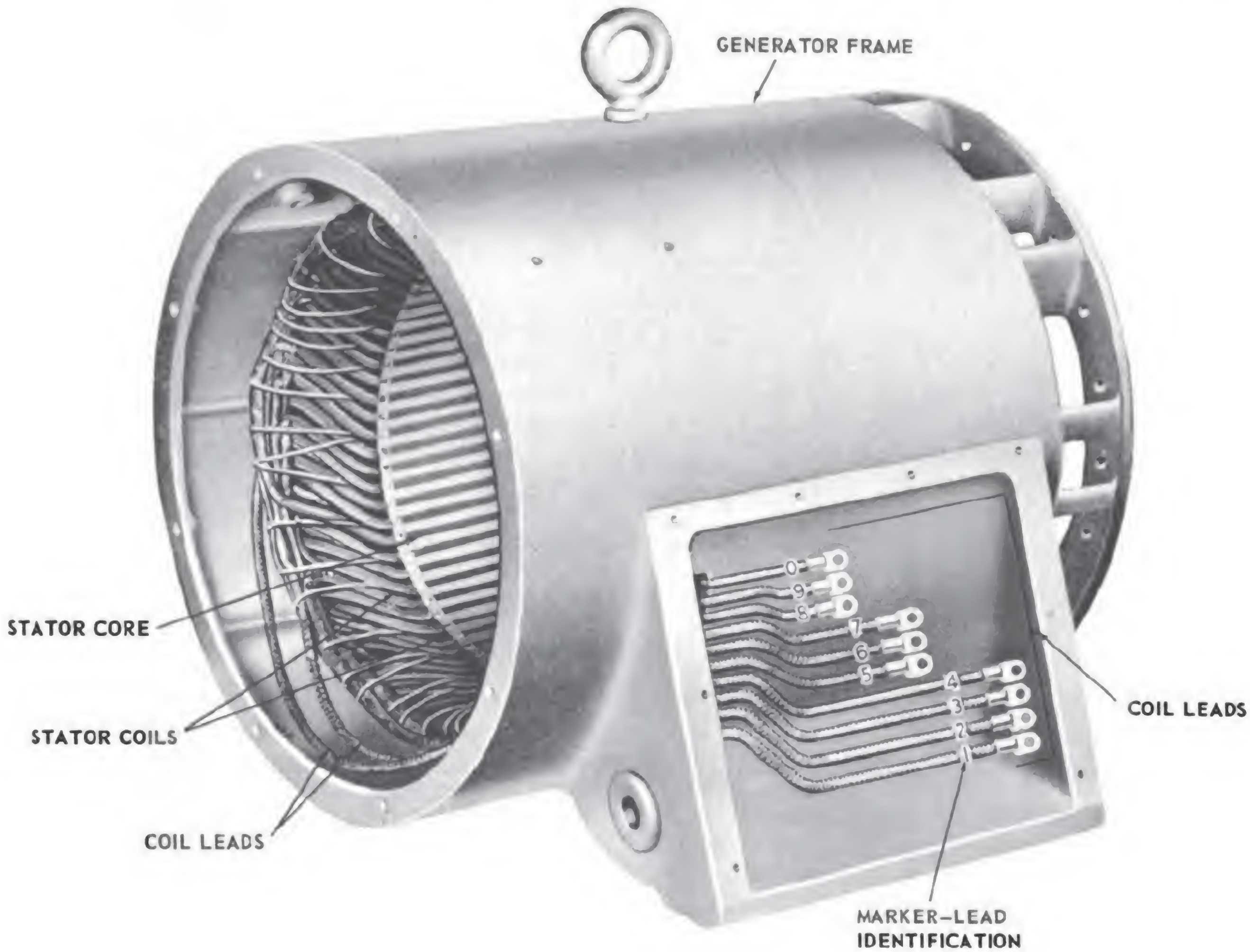


Figure 5-9.—Alternator coil leads. 26.72

generator so that it will have an output voltage of 440 volts. In its original connection (220-volt output), the generator was capable of carrying a full-load current of 264 amperes. Changing over to 440 volts, however, reduces its full-load current to 132 amperes. The first thing you will want to check, then, is the fuse rating in the main circuit breaker. You will probably find that for its original connection—220 volts, 264 amperes—the generator was protected by a 275-ampere trip element (fuse). To protect the generator for its new current rating (132 amperes), it will be necessary to replace the 275-ampere fuse with one having a 150-ampere rating.

Another thing to consider when reconnecting a generator is the switchboard ammeter instrument that records the current output of the unit. Since it is impractical to use an ammeter capable of carrying the full-load current, instrument transfers are employed. The instrument transformer reduces the current value to one that may be safely measured by the ammeter. Usually, the instrument transformer is designed to reduce the full-load current to a secondary current of 5 amperes. In turn, the ammeter, which is connected to the transformer's secondary, is designed to produce a full-scale deflection with an input of 5 amperes. Since the ratio between the load current and the current in the instrument transformer secondary is practically constant, the ammeter scale can be calibrated to read a true value of load current. Now, in the example being used, the generator has a full-load

Table 5-7.—Connections for Three-Phase Generators.

Required voltage	Connect line leads (via circuit breaker) to—			Connect	Tape individually
440-volts, three-phase, 3-wire.	T1----------	T2----------	T3----------	T4 to T7-------- T5 to T8-------- T6 to T9--------	
127/220-volts, three-phase, 4-wire.	T1 and T7----	T2 and T8----	T3 and T9----	T4, T5, T6, and T0 for neutral.	
220-volts, single-phase, 2-wire.	T2 and T8----	------------	T3 and T9----	T5 to T6--------	T1, T4, T7, T0.
220/440-volts, single-phase, 3-wire.	T3----------	T2 and T9, neutral.	T8----------	T5 to T6--------	T1, T4, T7, T0.
440-volts, single-phase, 2-wire.	T3----------	------------	T8----------	T2 to T9-------- T5 to T6--------	T1, T4, T7, T0.

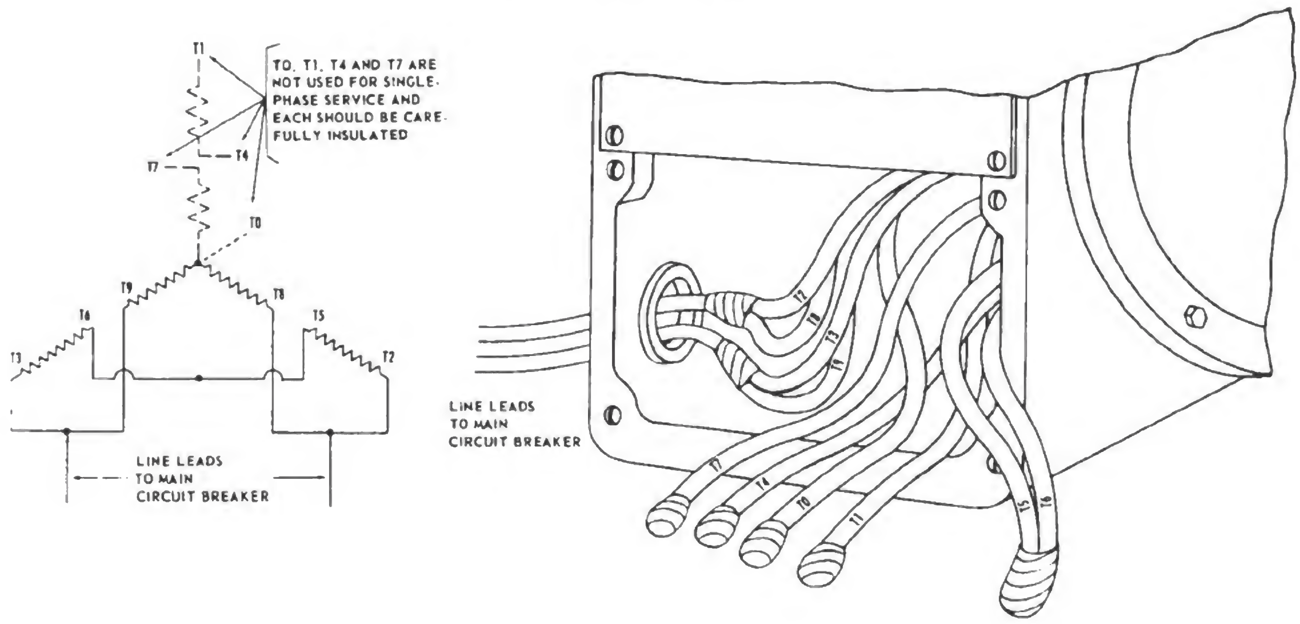


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Figure 5-10.—220-volt, single-phase connections.

current of 264 amperes when it is connected for a 220-volt output. That means that the instrument transformer will induce 5 amperes of current in its full secondary winding when 264 amperes flows in the line and, as a result, the ammeter will have a full-scale deflection. However, on reconnecting the generator for 440 volts, the full-load current is reduced to 132 amperes. Unless you alter the instrument transformer connections, full-load current will produce only a half-scale deflection of the ammeter and a resultant false reading. In this particular case, the alteration consists of moving the instrument transformer winding connection from the full-winding position to the mid-tap position. Most switchboard ammeters have an additional calibrated scale which makes it unnecessary to apply a correction constant when the current range is changed.

Another alteration that you may have to make in the generator's switchboard wiring concerns the voltage regulator. Essentially, the purpose of this device is to keep the generated voltage within certain limits regardless of changing load conditions. Although there are many types of voltage regulators they all respond to VARIATIONS IN RATED LINE VOLTAGE. However, the line voltage is not applied directly to the regulator unit. A potential transformer is employed to reduce the line voltage to a standard value that is safe to use on the regulator. The ratio of primary voltage to secondary voltage must remain constant if the regulator is to function properly within the limits of the generator's rated voltage. Therefore, when the output voltage of the generator is changed, you must also change the tap connections on the primary of the potential transformer.

Probably the big question in your mind is, "Do these alterations require that you actually dive into the maze of wiring behind the generator's switchboard and move leads from one terminal to another?" Generally no. In a few cases you may have to change the leads. The majority of manufacturers have made provisions that simplify the changeover from one voltage output to another. Typical of these changeover provisions is the generating set illustrated in figure 5-11. Essentially, it consists of a 6-bladed, double-throw VOLTAGE SELECTOR SWITCH mounted on a terminal board. As shown in the end view of the generating set (fig. 5-11), the terminal board is mounted in the lower right-hand corner of the frame. The three vertical rows of the switch contacts extend through the terminal board and are connected permanently, by means of wires, to the generator's stator coil leads; the current and potential transformer windings; the instruments and controls on the switchboard; and the circuit

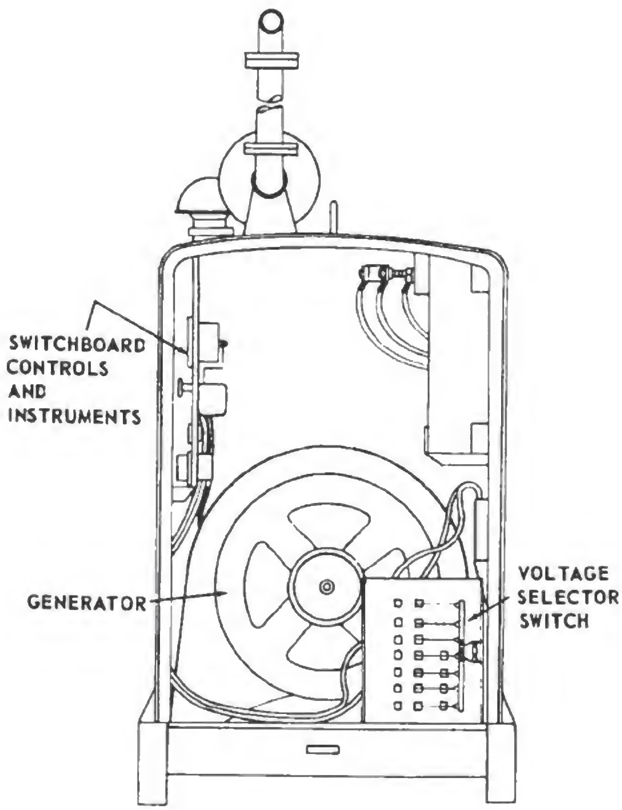

Figure 5-11.—Voltage selector switch on a typical generating set.

breaker. The arrangement of the wires is such that when the switch is thrown to the left the stator coil leads are automatically connected to produce an output voltage of 220 volts, and the current and potential transformers windings are tapped at the correct point for proper operation of the switchboard's instruments and controls. When the selector switch is thrown to the right, the wiring arrangement automatically connects the stator coil leads for a 440-volt output and taps the instrument transformer windings for correct outputs in accordance with the generator's new voltage and current range.

One type of change-over device in advanced base generators is shown in figure 5-12. It is a CHANGEOVER BLOCK that is mounted on the rear of the generator's switchboard (control cabinet). The terminal studs that protrude from the changeover block serve two purposes: they provide a disconnect point between the load cables and the generator coil leads, and they present a convenient means of altering the operating characteristics of the generator's components without changing the positions of the wires. Notice that each of the 10 generator stator coil leads is attached to a correspondingly numbered terminal stud. Rearrangement of the coil leads becomes a simple process of interconnecting the terminal studs in a definite pattern by the use of CHANGEOVER LINKS (fig. 5-12). When in position on the coil lead terminal studs, the changeover links also contact other studs that are connected to such components as the current transformers, and the potential transformers. Thus, alteration of these components output is also changed automatically. Connection diagrams on a nameplate attached to the changeover block provide the necessary information as to the position of the changeover links for specific voltage outputs.

Remember that you are responsible for the proper operation of the generating unit. Therefore proceed with caution on any reconnection job. Study the wiring diagrams of the plant and follow the manufacturer's instructions to the letter. Before you start the plant up and throw the circuit breaker, do a double-check on all connections.

BUS BAR

There are a number of reasons why it is sometimes necessary to use a bus bar when you set up a portable generating station. For one thing, you may not be able to acquire a generating plant that has sufficient capacity to meet the total power demand of the electrical load. It will be necessary, then, to use two or more generating units and collect their paralleled outputs at one central point (the bus bar). Or, you may discover that the electrical equipment in the advanced base is scattered in such a manner as to require the use of feeder (branch) lines that can be controlled from a central source. Again, the bus bar is the answer.

A typical advanced base generating station using a bus bar is shown in figure 5-13 (circuit breakers are enclosed in the generator). The two generators are leveled on a concrete apron that is sloped for drainage. The electrical output of each generator is transferred underground to the bus bar by four, single-conductor cables. The bus bar itself consists of four cables stretched between two 4 by 4 posts. A secondary

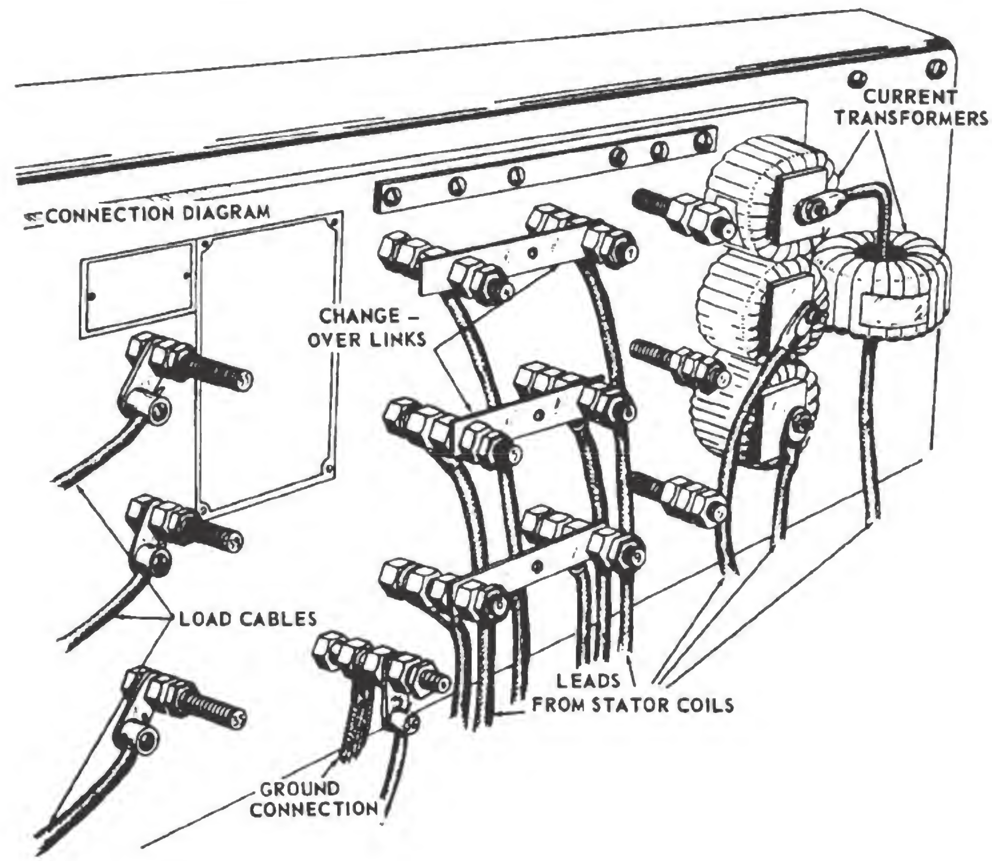

Figure 5-12.—Typical changeover block showing generator and loadconnecting points. 26.75

rack mounted on each post serves as an insulating support for the bus-bar cables. Two switches, one for each feeder line, are mounted abovr the bus bar. A wooden platform provides an insulating medium for operating personnel.

Whether or not your bus-bar installation looks exactly like the one in figure 5-13, the point to remember is that the equipment should be properly secured and supported, and where necessary, properly insulated. The size of wire will depend on the load current. The switches that control the output to each feeder line can either be of the fused knife switch or the circuit-breaker type. Be sure that the current rating of the fuses or trip element will provide adequate protection against excessive overloads or short circuits on the feeder lines. Also make certain that the components of the circuit breaker or switch (i.e., the switch blades and breaker contacts) are capable of carrying the rated current and voltage of the feeder lines. In addition, make every effort to protect the switch-gear and bus bar from the weather. Building a weatherproof canopy over the rack will help ensure uninterrupted service and protection for personnel.

POWER PLANT (GENERATOR) OPERATION

Setting up a power generator is only one phase of your job. After the plant is set up and ready to go, you will be expected to supervise the activities of the operating personnel of the generating station. In this respect, your supervision should be directed toward one ultimate goal--to maintain a continuous and adequate flow of electric power to meet the demand. This can be accomplished if you have a thorough knowledge of how to operate and maintain the equipment and a complete understanding of the

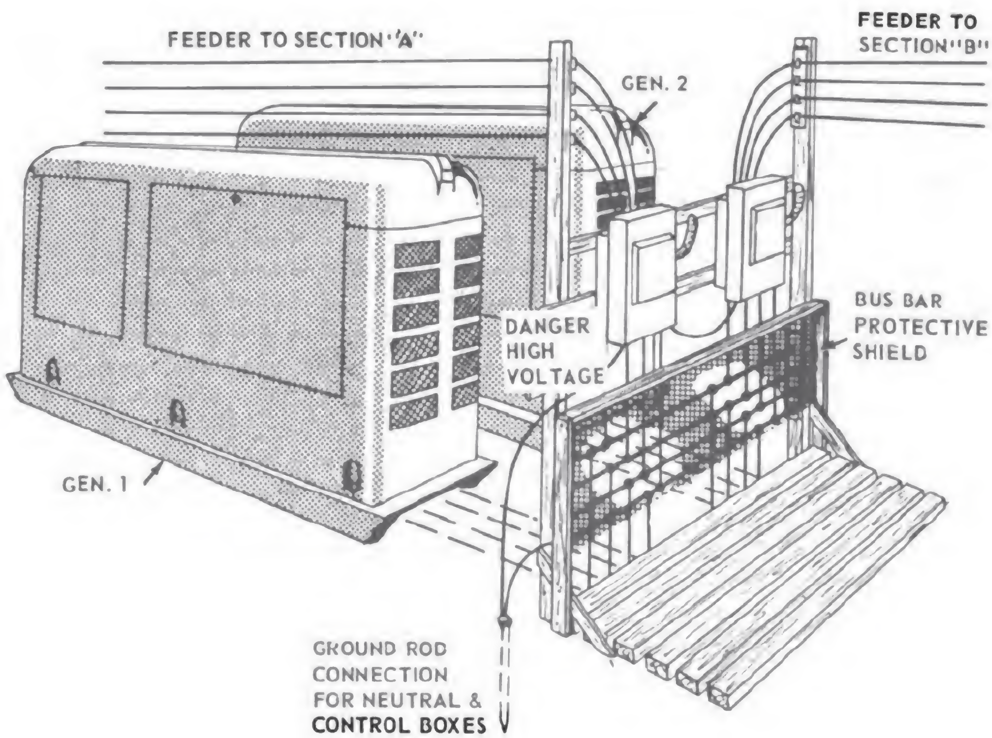

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Figure 5-13.—Typical bus bar installation.

station's electrical system as a whole. Obviously, a thorough knowledge of how to operate and maintain the specific equipment found in the generating station to which you are assigned cannot be covered here. However, general information can be given. It will be up to you to supplement this information with the specific instructions given in the manufacturer's instruction manuals furnished with each piece of equipment. Similarly, familiarity with the station's electrical system as a whole can be gained only by a study of information relating specifically to that installation. This information can be found to some extent in the manufacturer's instruction manuals but the greater part of it will be obtained from the station's electrical plans and wiring diagrams. Remember, however, that a study of the electrical plans and diagrams must be supplemented with an actual study of the generating station's system itself. In that way the generators, switchgear, cables, and other electrical equipment are not merely symbols on a plan but physical objects whose location is definitely known, and whose functions and relation to the rest of the system are thoroughly understood.

GENERATOR WATCH

When you are in charge of a generating station, you will be responsible for scheduling around-the-clock watches to ensure a continuous and adequate amount of electrical power. Depending on the number of operating personnel available, the watches are evenly divided over the 24-hour period. It is common practice to schedule 6-hour watches, or they may be stretched to 8-hour watches without working undue hardship on the part of the crew members. Watches exceeding 8 hours, however, should be avoided unless emergency conditions dictate their use.

The duties assigned to the men on generator watches can be grouped into three main categories: (1) operating, the equipment, (2) maintaining the equipment and (3) keeping the daily operating log. Operating and maintaining the generating equipment will be covered in succeeding sections of this chapter, so for the present you can concentrate on the importance of the third duty of the station operator—keeping a daily operating log.

The number of operating hours are recorded in the generating station log. The log serves as a basis for determining when a particular piece of electrical equipment is ready for inspection and maintenance. The station log can be used in conjunction with previous logs to spot gradual changes in equipment condition which ordinarily are difficult to detect in day-to-day operation. It is particularly important that you impress upon your men the necessity for making accurate recordings at periods specified by local operating conditions.

Ensure that watch standers keep their spaces clean and orderly. Impress on them the importance of keeping tools and auxiliary equipment in their proper place when not in use. Store clean waste and oily waste in separate containers. OILY WASTE CONTAINERS MUST BE KEPT COVERED. Empty oily waste containers at least once a day to reduce fire hazards. Care given the station floor will be governed by its composition. Generally, it should be swept down each watch. Any oil or grease that is tracked around the floor should be removed at once.

SWITCHGEAR

Switchgear as you know is a term covering the switching and interrupting devices with their components that control, meter, protect and regulate power equipment. Your inspection and maintenance schedule for the switchgear equipment will be determined for the most part by local operating conditions and the recommendations of the manufacturer. In general, a check and inspection should be made at least once a year. The procedure for maintaining and inspecting switchgear equipment is covered in the Construction Electrician Course 3 and 2 training course.

The operation, maintenance and repair of circuit breakers is covered in chapter 3 of this course.

SINGLE PLANT OPERATION

Connecting an electric plant to a deenergized bus involves two general phases: (1) starting the diesel engine and bringing it up to rated speed under control of the governor and (2) operating the switchboard controls to bring the generator's power onto the bus.

The instructions which follow apply for single operation of the 600-kw generator, described earlier in this chapter. The unit has been grounded, leveled, and properly blocked. Proceed as follows:

1. Unfasten all radiator shutter locks; open the two forward side doors of the cab and two forward roof hatches; open the main engine exhaust stack and cable door; remove the cable from cable reel and make necessary connections to the unit receiving power and to two ground connections.
2. Install suitable lightning arresters when service is supplied to an overhead line.
3. Check the lube oil, cooling water, and fuel supply, and see that they are at the proper level; be sure that the air storage tank has a pressure of 150 psi.
4. If cab temperature is below 45°F, start oil-fired cooling system heater by turning the heater switch to ON position, HIGH or LOW as conditions require. Allow heater to operate until main engine temperature reaches 80°F.
5. If specific gravity of storage battery is 1.200 hydrometer reading or lower, the battery charging rectifier must be started, using either outside power source or auxiliary generator for current supply to rectifier.
6. Check control panel for proper changeover link arrangement: delta connection for 2400v or star connection for 4160v.
7. Start air compressor if air pressure in receiving tank is less than 150 psi.
8. Check to make certain the shipping blocks are removed from the voltage regulator, three overcurrent relays, and reverse power relay.
9. If lube oil level in main engine base is low, close the circulating control valve and open the intake valve on lube oil lines under main engine lube oil filter and start lube oil circulating pump. WARNING: Close the intake valve and open the circulating control valve immediately when oil gage in main engine base indicates FULL.
10. Fill auxiliary engine fuel storage tank by closing the fuel control valve, open the fuel intake valve and work hand transfer pump lever back and forth until tank is full.
11. Close the fuel intake valve and open the fuel control valve to prime main engine fuel system. Work hand pump until 25 psi of fuel pressure shows on the engine instrument panel gage.
12. Open the valve on main air supply to main engine air-starting motor.

13. Move ON-OFF switch on engine panel to ON position.

14. Set LOAD LIMIT dial on main engine governor to No. 10 position and the SYNCHRONIZING dial at No. 5 position.

15. Hold down safety control switch, on engine panel, and press starting switch, until engine starts. Continue to hold safety control switch until 30 psi oil pressure shows on engine lube oil pressure gage.

16. Reset annunciator; clear it, if necessary.

17. Check indicating lamps on engine panel to determine that radiator shutters are unlocked; lamps are red if shutters are locked.

18. Check color of indicating lamps on electric panel for proper voltage connection, amber for delta at 2400v and blue for star at 4160v.

19. Adjust field rheostat and voltage regulator to obtain desired voltage.

20. Turn incoming synchronizer to ON position and engage main circuit breaker.

21. Adjust frequency to 60 cycles with governor control switch on electric panel.

22. Place power switch on electric panel to TRANSF for power supply from main engine.

PARALLEL OPERATION

The following is a general guide to the operator when placing two 600-kw units (described earlier in this chapter) in parallel operation. The units should be thoroughly warmed before any attempt is made to place them in parallel. After the units attain proper operating temperatures, you should set the engine speed to 1200 rpm, 60 cycles and then properly adjust the governors. To prevent shifting of this load from one unit to the other during parallel operation, adjust one engine governor with zero droop to maintain frequency. The other unit(s) that are to be placed in parallel on the line load must be set with the proper speed droop to carry the desired portion of the load. The zero-droop engine will absorb all load changes and maintain any frequency for which it is set until it becomes overloaded or until its load is reduced to zero. The droop units will assist in correcting speed changes on large load disturbances but will return to their original loads after the load change has been absorbed by the zero-droop unit.

The following steps must be followed to obtain the above mentioned results:

1. Adjust one engine governor to zero droop with the governor speed droop dial.

2. Adjust additional units to speed droop required to handle desired portion of load (30-50) setting recommended. NOTE: No more than one unit may be adjusted with zero droop when operating in parallel.

3. Place synchronizing switch in ON position and note phase rotation indicated by synchronizing lamps and synchroscope on the electric panel. NOTE: synchronizing lamps will get dark and bright alternately when phase rotation is correct.

4. Change voltage changeover switch to AUTO position and remove all exciter resistance by turning the exciter rheostat slowly to its extreme counterclockwise position.

5. Adjust the voltage of the incoming unit, using the voltage regulator rheostat, to the identical voltage indicated on the bus voltmeter.

6. Adjust the frequency of the incoming unit, using the governor control switch, until the synchroscope hand slows and stops at 12 o'clock.

7. After the circuit breaker of the incoming unit is thrown, check and adjust the load distribution by adjusting the governor speed control switch on the electric panel: FASTER to add load and SLOWER to remove load.

8. Maintain approximately one-half load on the zero droop unit by manually adding or removing the load from the speed-droop units as described in step 7.

9. Repeat the procedure listed in steps 1 through 8 for each additional unit to be paralleled.

After the engines are adjusted as described herein, the units should handle normal load fluctuations without further adjustments provided that the engine governors are adjusted properly.

Emergency Shutdown (600-kw generator)

In the event of engine overspeed, high jacket water temperature, and/or low lubricating oil pressure, the engine may be shut down and disconnected from the main load by tripping the main circuit breaker. In addition, an alarm will sound to indicate the cause of shutdown. After an emergency shutdown and before the engine is returned to operation, the cause of shutdown should be investigated and corrected. NOTE: It is important to check the safety controls at regular intervals to determine that they are in good working order.

OPERATING RULES AND SAFETY PRECAUTIONS

The orders that you post in the station for the guidance of the watch standers should include a general list of operating rules and electrical safety precautions. BE SURE YOU ENFORCE THEM!

The important operating rules are relatively few and simple. They are:

1. Watch the switchboard instruments. They show how the system is operating, reveal overloads, improper division of kilowatt load or of reactive current between generators operating in parallel, and other abnormal operating conditions.

2. Keep the frequency and voltage at their correct values.

A variation from either will affect, to some extent at least, the operation of the base's electrical equipment. This is especially true of such equipment as teletypewriters or electric clocks. To maintain reasonably constant frequency, an electric clock and an accurate mechanical clock should be installed together at the powerhouse so that the operators can keep the generators on frequency.

3. USE GOOD JUDGMENT WHEN RECLOSING CIRCUIT BREAKERS AFTER THEY HAVE TRIPPED AUTOMATICALLY. For example, generally the cause should be investigated if the circuit breakers trips immediately after the first reclosure. However, reclosing of the breaker the second time may be warranted if immediate restoration of power is necessary and there was no excessive interrupting disturbance when the breaker tripped. It should be kept in mind however, that repeated closing and tripping may damage the circuit breaker and thus increase the repair or replacement work.

4. Don't start a plant unless all its switches and breakers are open and all external resistance is in the exciter field circuit.

5. Don't operate generators at continuous overload. Record the magnitude and duration of the overload in the log; record any unusual conditions or temperatures observed.

6. Don't continue to operate a machine in which there is vibration until the cause is found and corrected. Record the cause in log.

The electrical safety precautions that should be observed by the station personnel are:

1. Treat every electrical circuit, including those as low as 35 volts, as a potential source of danger.

2. Except in cases of emergency, never allow work on an energized circuit. Take every care to insulate the person performing the work from ground. This may be done by covering any adjacent grounded metal with insulating material such as dry wood, rubber mats, dry canvas, or even with several thicknesses of heavy dry paper. In addition provide ample illumination; covering working metal tool with insulating rubber taps; stationing men at appropriate circuit breakers or switches so that the switchboard can be deenergized immediately in case of emergency; and make available a man qualified to render first aid for electric shock.

REMINDER

Inspection and servicing procedures covered in this chapter are rather general. In most cases they can be applied to any electric power generator that you install. You realize of course, that there are other special installation details which pertain only to the particular generator you happen to be working on. Because of the many different types of generators there are instructions that are applicable to a specific type of generator. Therefore, you should consult the manufacturer's instruction manuals for these details. SAVE THESE INSTRUCTION MANUALS! Additional copies are rarely available.

You must keep in mind that you are responsible for any failure of the generator(s) due to improper servicing and operation by your crew. It is the small precautions that are overlooked that cause most generators to fail. Are your crew members servicing and inspecting the equipment according to prescribed procedures? Did you instruct your men on proper safety procedures? Are you enforcing these rules? Safety warnings such as keeping the funnel in contact with the fuel tank when filling it with gasoline might save a life and ensure a full working crew.

CHAPTER 6

POWER DISTRIBUTION SYSTEM

COMPONENTS OF THE SYSTEM

A distribution system includes all parts of an electrical system between the power source and the customer's service entrance. The power source may be either a local generating plant or a high-voltage transmission line feeding a substation which reduces the high voltage to a voltage suitable for local distribution (See fig. 6-1.) The problem of distribution includes the design, construction, operation, and maintenance of a distribution system that will economically supply adequate electric service to the load area. At most advanced bases the source of power will be generators connected directly to the load.

A power distribution system may be either an overhead distribution line or an underground cable system. In most Navy installations, however, the overhead system is used. This chapter will therefore be mainly concerned with the overhead distribution system.

Generally speaking, an overhead distribution system can be installed and maintained more cheaply than an underground system. Also, for equivalent conductor size, an overhead system has higher current capacity and offers greater flexibility with regard to changes in circuits and taps than an underground system. Overhead distribution should normally be used unless climatic or unusual conditions dictate otherwise. In the vicinity of airports or landing strips, for example, it may be necessary to install an underground distribution system.

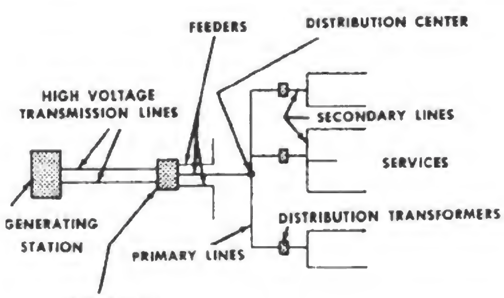

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Figure 6-1.—A transmission and distribution system.

On most Navy installations and at some advance bases, the primary voltages are 2400/4160 three-phase four-wire 60 cycle systems. The secondary line voltage is normally 120/208 volts, and is supplied to the load through a transformer or transformer banks.

PRIMARY FEEDERS

Primary feeders are those conductors in a distribution system that are connected to the substations and extend to the distribution centers. (See fig. 6-1.) They may be arranged as radial, loop, or network systems.

Radial Distribution System

A typical schematic of a radial distribution system is illustrated in figure 6-2. You will note the independent feeders branch out to several distribution centers without intermediate connections between feeders.

The radial distribution system is the most frequently used system, because it is the simplest and least expensive system to build. It is

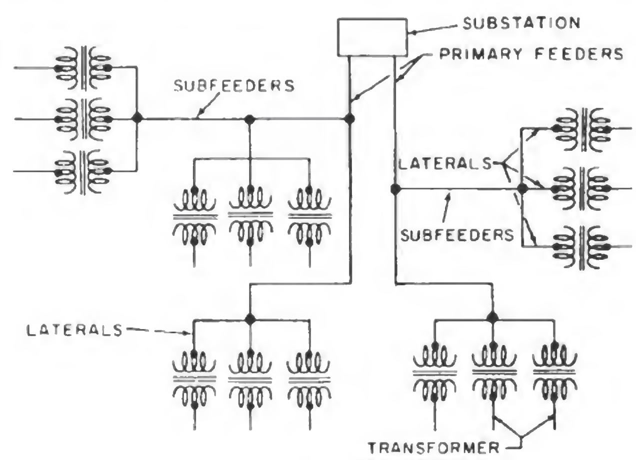

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Figure 6-2.—Primary radial feeder.

not as reliable as most systems, however, because a fault in the main feeder may result in an outage on all loads served by the feeder.

The service on this type of feeder can be improved by installing automatic reclosing circuit breakers, which will reclose the service at predetermined intervals. If the fault continues after a predetermined number of closures, the breaker will be locked out until the fault is cleared and service is restored by hand reset.

Loop or Ring System

The loop (or ring) system starts at the substation, and is connected to or encircles an area serving one or more distribution transformers or load centers; the conductors of the system return to the same substation.

The loop system (fig. 6-3) is more expensive to build than the radial type, but it provides a more reliable system. It may be justified in an area where continuity of service is of considerable importance — at a medical center for example.

In the loop system, circuit breakers sectionalize the loop on both sides of each distribution transformer connected to the loop. The two primary feeder breakers and the sectionalizing breakers associated with the loop feeder are ordinarily controlled by pilot wire relaying or directional overcurrent relays. Pilot wire relaying is used when there are too many secondary substations to obtain selective timing with directional overcurrent relays.

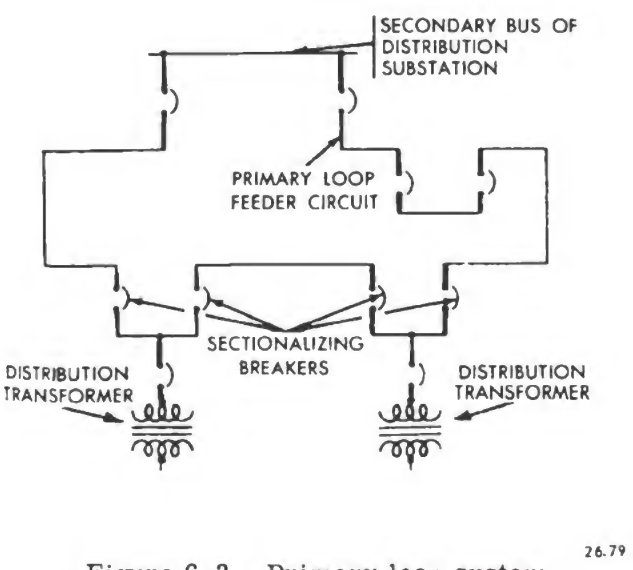

Figure 6-3.—Primary loop system.

A fault in the primary loop is cleared by the breakers in the loop nearest the fault, and power is supplied the other way around the loop without interruption, to most of the connected loads. If a fault occurs in a section adjacent to the distribution substation, the entire load may have to be fed from one direction over one side of the loop until repairs are made. Sufficient conductor capacity must be provided in the loop to permit operation without excessive voltage drop or overheating of the feeder when either side of the loop is out of service. If a fault occurs in the distribution transformer, it is cleared by the breaker in the primary leads, and the loop remains intact.

Network System

The network and radial systems differ with respect to the transformer secondaries. In the network system, transformer secondaries are paralleled; in a radial system they are not.

The network is the most flexible type of primary feeder system; it provides the best service reliability to the distribution transformers or load centers, particularly when the system is supplied from two or more distribution substations. Power can flow from any substation to any distribution transformer or load center in the network system. The network system is more flexible with regard to load growth than the radial or loop system and is adaptable to any rate of load growth. Service can readily be extended to additional points of usage with relatively small amounts of new construction. The network system, however, requires large quantities of equipment and extensive relaying; it is therefore more expensive than the radial system. From the standpoint of economy, the network system is suitable only in heavy-load-density areas where the load center units range from 1000 to 4000 kva. (See fig. 6-4.)

Primary Selective System

In some instances a higher degree of reliability can be attained with a primary selective system. In such a system, two feeders supply a single load center, with switching arranged for selection of either feeder. This selection may be made manually or automatically.

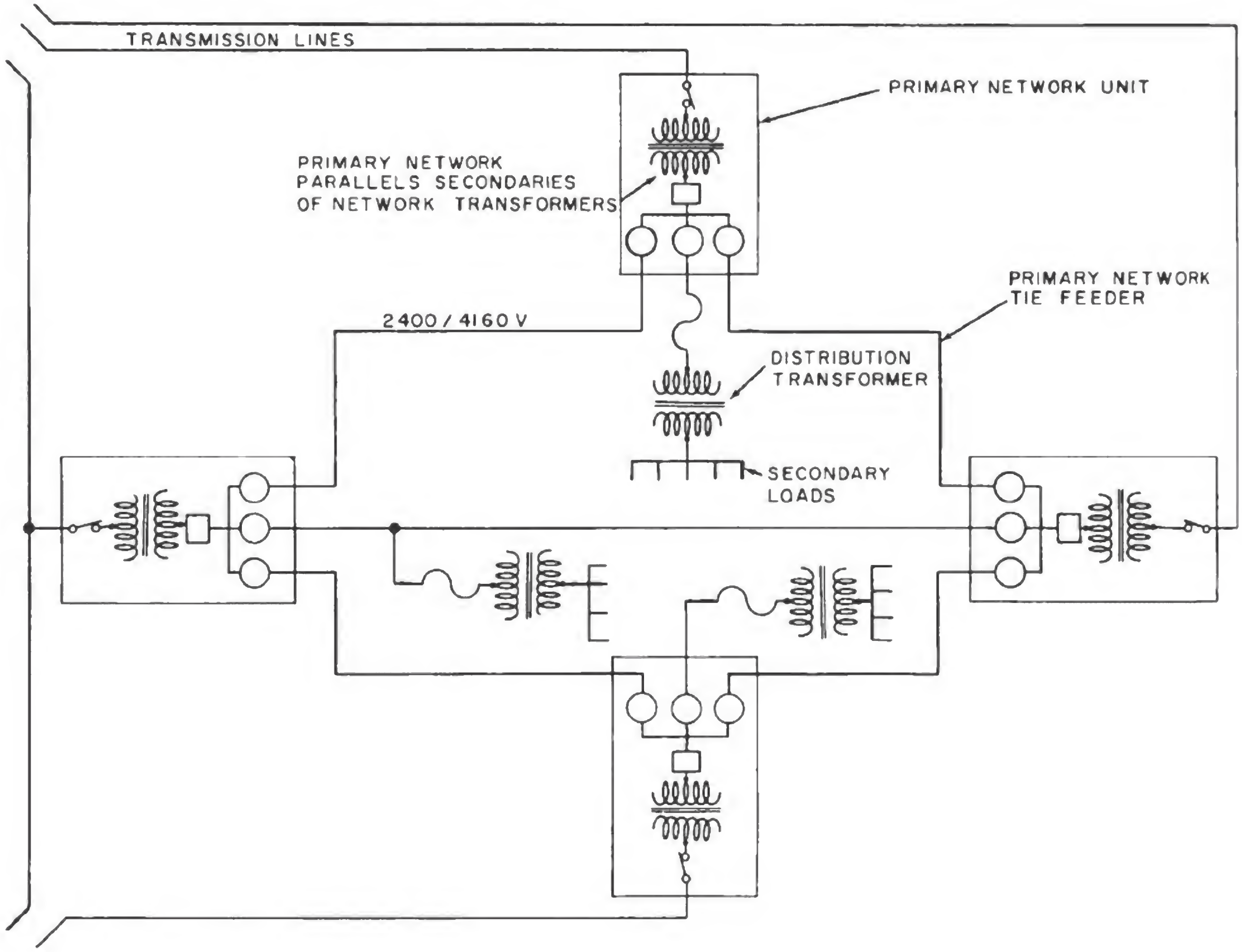

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Figure 6-4.—Primary network system.

DISTRIBUTION CENTER

The distribution center (fig. 6-5a and fig. 6-5b) is the location at which the primary main is connected to the feeder circuit. The fused cutout switch for the control and protection of the primary main is usually mounted on the buck-arm below the primary main at the distribution center (fig. 6-6). The voltage at the distribution center should be maintained practically constant from no load to full load. Constant voltage can be maintained by a feeder voltage regulator at the substation. The voltage can then be held constant at the distribution center by varying the voltage at the substation.

PRIMARY MAINS

The primary mains are connected to the feeder at the distribution load center. They are always located below the feeder on a pole. The primary mains operate at the same voltage as the feeder. The distribution transformers are connected to the primary mains through fused or automatic cutouts. Figure 6-6 shows the primary main to which the transformer is tapped. The cutouts, one on each primary line contain the fuses which protect the transformer against overload and short circuits. The primary mains are strung across the upper crossarm and usually lie in a horizontal plane.

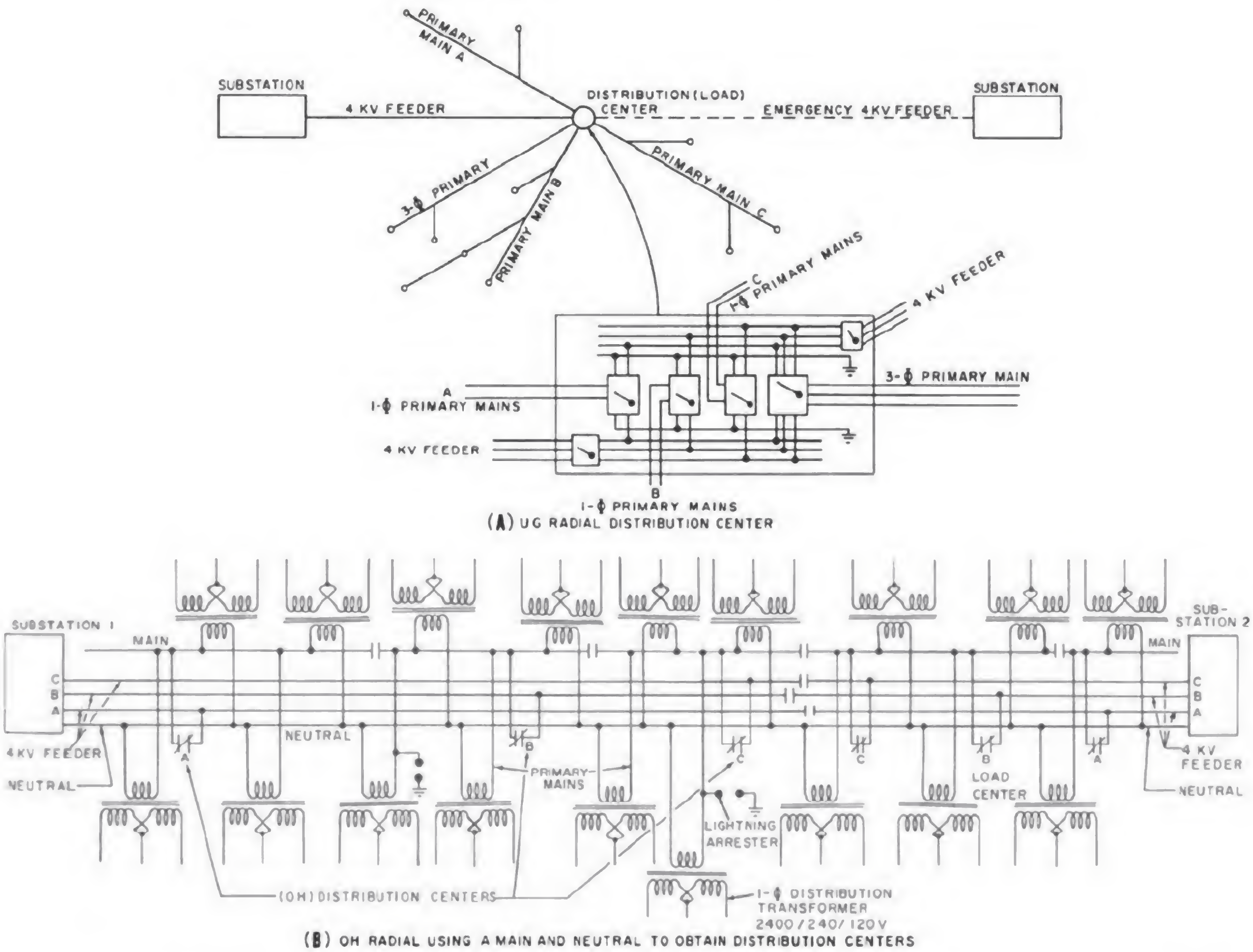

Figure 6-5.—(Load) Distribution Centers on radial systems (O.H. & U.G.).

In laying out a distribution system for a base, the base area should be divided into a number of sections. These sections should be chosen so that the loads in each section are close to one of the distribution centers. You do this to keep the length of the mains as short as possible, and to keep the voltage drop low between the distribution and the loads. The distribution or load centers should be located as near as possible to the center of the area of the connected load.

DISTRIBUTION TRANSFORMERS

Most electrical equipment in the Navy utilizes 120/208 volts. The primary voltage distributed on Navy shore installations, however, is usually 2400/4160. A distribution transformer (step down) is therefore, required to reduce the high primary voltage to the utilization voltage of 120/208 volts. The various types of transformer installations are discussed later in the chapter. Regardless of the type of installation or arrangement, transformers must be protected by cutout fuses or circuit breakers, and lightning arresters should be installed between the high voltage line and the fused cutouts.

There are three general types of single-phase distribution transformers. The conventional type requires a lightning arrester and fused cutout on the primary phase conductor feeding it. The self-protected (SP) type has a

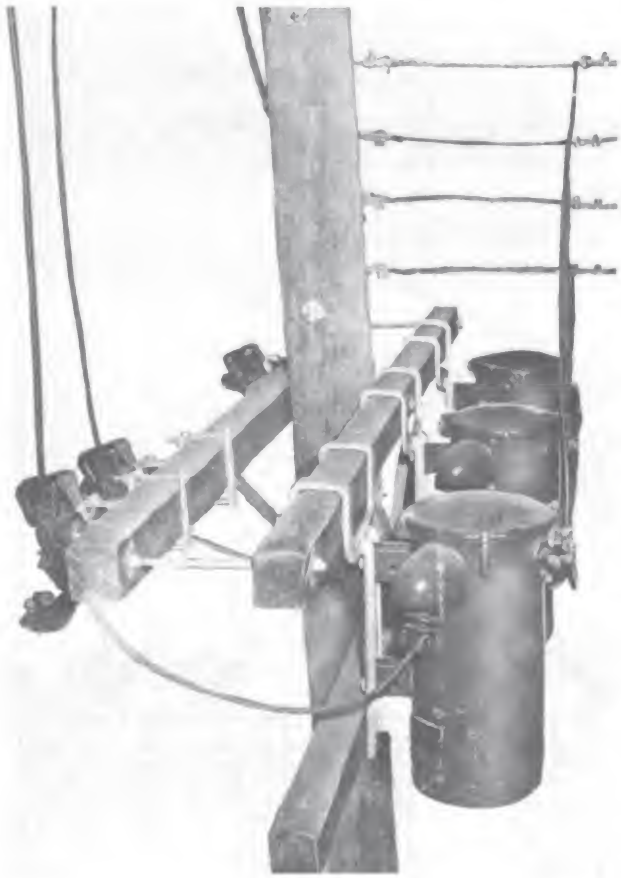

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Figure 6-6.—Pole mounted three-phase installation.

built-in lightning protector; the completely self-protected type (CSP) has both the lightning arrester and the current-over load devices connected to the transformer and requires no separate protective devices.

Transformer Maintenance

Substation transformers should be inspected once a month to see that the oil is at the proper level. Most substation transformers have a liquid-level gage showing the correct level for 25°C. Small distribution transformers are marked for correct oil level inside the tank. Too little liquid will cause deterioration from overheating or insulation breakdown; too much liquid in sealed-in transformers may result in excessive tank pressures. Because the dielectric strength of oil should not go below the requirement of 22,000 volts with a 0.1-inch gap, periodic tests are necessary. New oil usually tests 26,000 volts or more. A test schedule should be set up for each transformer. Samples should be drawn from the bottoms of the tanks and inspected for discoloration, carbon, or sludge at least once each year.

You should also test the oil for moisture. Moisture decreases dielectric strength, and in spite of all precautions, may be absorbed by the transformer. Moisture in the oil may be detected by observation or by dielectric tests; moisture in the windings or other parts cannot be so readily detected. The two most common methods of detecting moisture are checking the condition of the insulation-resistance and power-factor testing. The latter tests the capacitance and power factor of transformer bushings. The power factor increases with leakage resistance. The importance of these tests cannot be overemphasized.

CAPACITORS

Another important part of the distribution system is the CAPACITOR. Capacitors are a convenient and practical means to improve the power factor by relieving lines of lagging currents. This action reduces the line current and line losses and improves the line voltage regulation. Capacitors can be installed in relatively small banks and placed on the circuit near the source of reactive lagging kva. Although keeping them on the primary feeders in banks of 45-kva or more is usually more desirable, three phase 15-kva units may be justified in some cases. Normally it is not desirable to improve the power factor above 90 percent, because the capacitive kva per ampere of line current, reduction becomes excessive, and is not economical. Size and location of capacitor installations must be approved by the officer acting as electrical superintendent. Typical capacitor installations are shown in figures 6-7 and 6-8.

Listed below are a few rules to help you supervise the installation of capacitors:

1. Use line type lightning arresters on the capacitor banks of the sizes normally used. Large banks require special consideration for proper application of lightning protective equipment.

2. Use primary cutouts in the majority of installations to connect and disconnect the capacitor bank. A liberal margin between normal current ratings and fuse rating is necessary

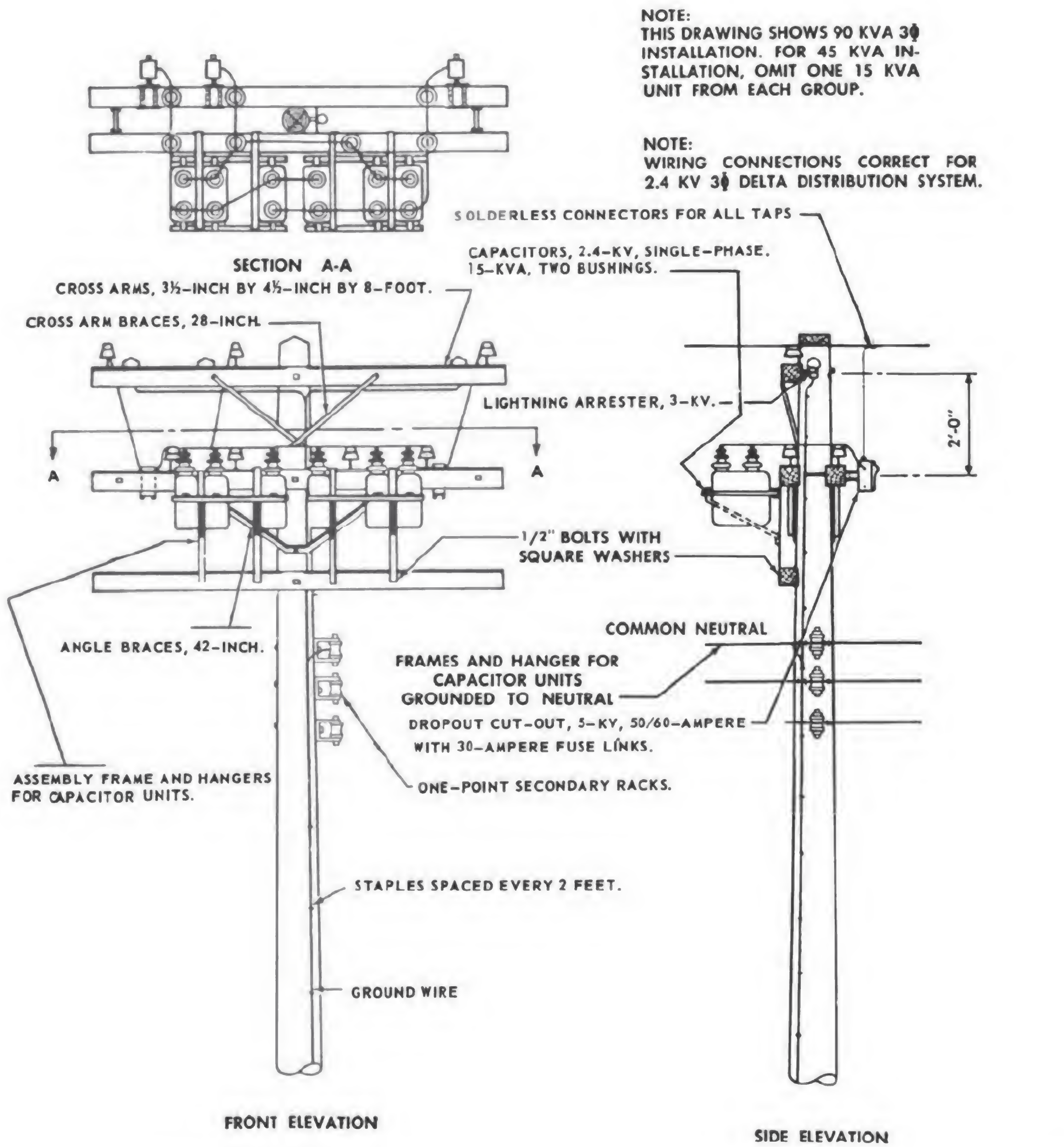


Figure 6-7.—Installation on distribution pole, delta primary.

to avoid unnecessary operation on current transients.

3. Use shunt capability to either increase the load capacity or improve line voltage.

4. Install capacitors at load centers for added load capacity.

5. Install capacitors at end of line for voltage improvement.

CAUTION: A disconnected capacitor retains its electrical charge for some time, and may have full line voltage across its terminals. A 5-MINUTE WAITING PERIOD MUST BE OBSERVED AFTER THE CAPACITOR IS DISCONNECTED, AND THEN IT SHOULD BE SHORT CIRCUITED AND GROUNDED BEFORE ANY WORK IS DONE ON IT.

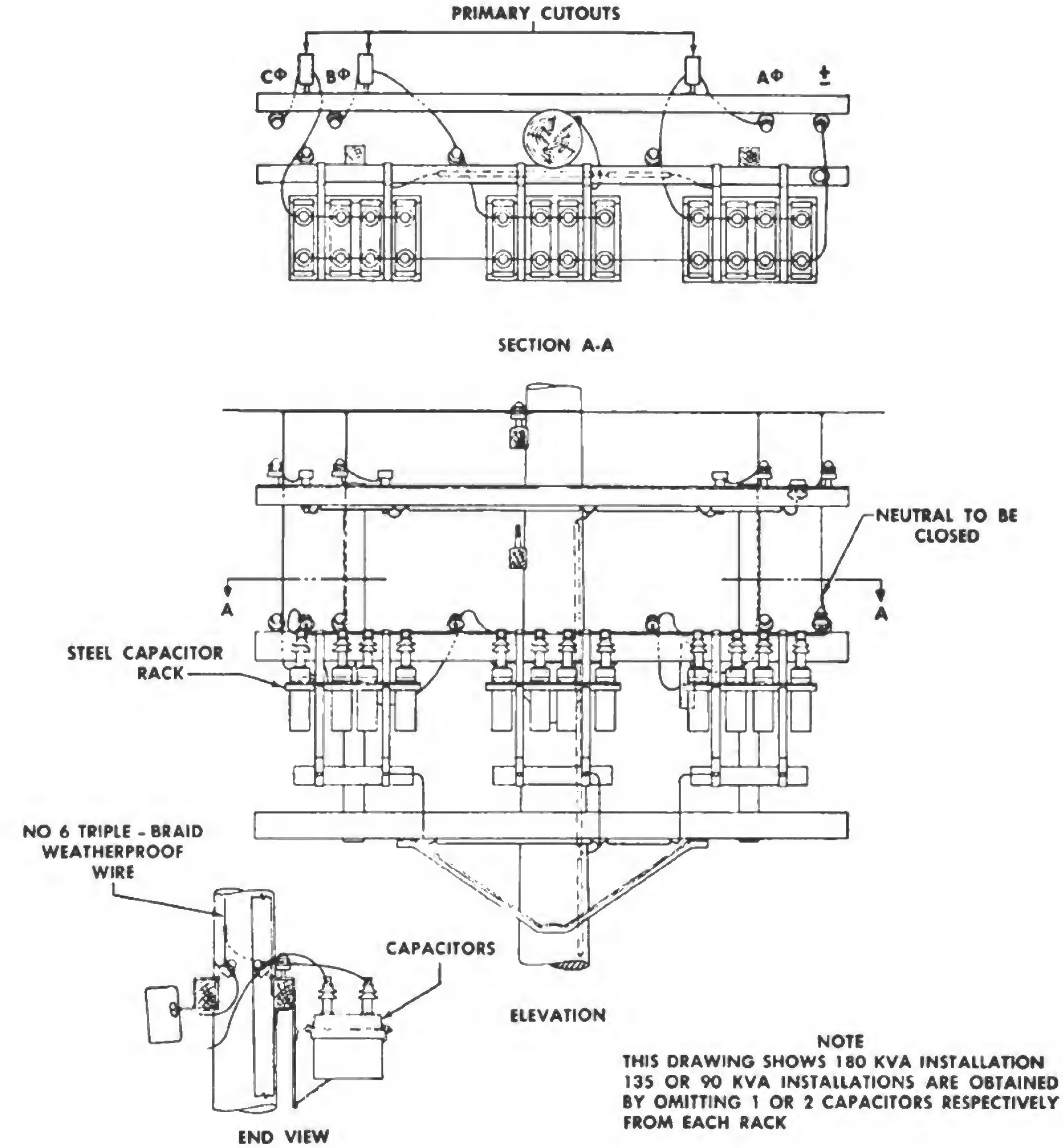


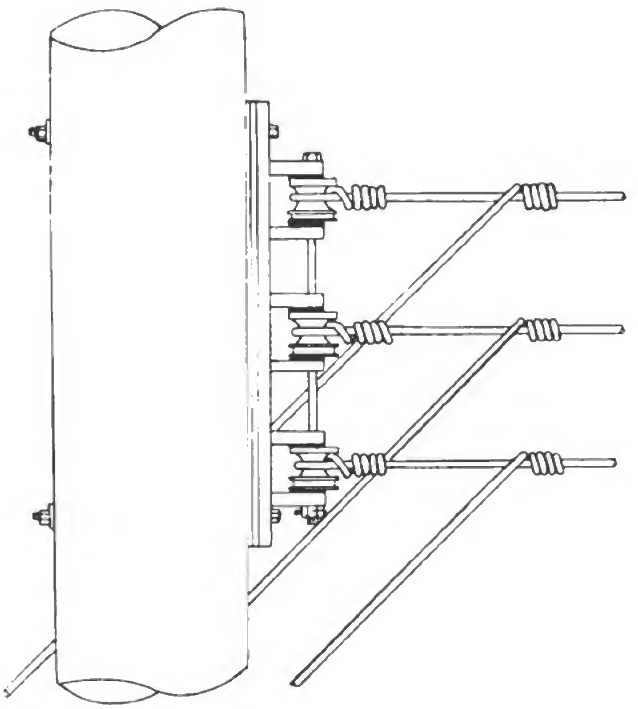
Figure 6-8.—Typical capacitor installation on distribution pole, four-wire, wye primary.

SECONDARY MAINS

The secondary distribution system is the last link between the generating station and the individual services. The secondary system includes the range of voltage at which lights, motors and equipment are operated.

Secondary mains can be supported vertically or horizontally. On naval installations, however, they are usually supported vertically on secondary racks or clevises. When a number of services run from each side of the pole, a secondary rack should be installed on the opposite side (fig. 6-9).

When your crew strings conductors on the secondary, make sure they string all the wire on the same side of the pole. This will make it more convenient to tap service drops. Also, when stringing wire in congested areas, the conductor should be unreeled and passed through the racks or clevises on the poles so that the conductor will not be in the path of any traffic. Where there is no traffic problem, all the conductors can be reeled out on the ground, then



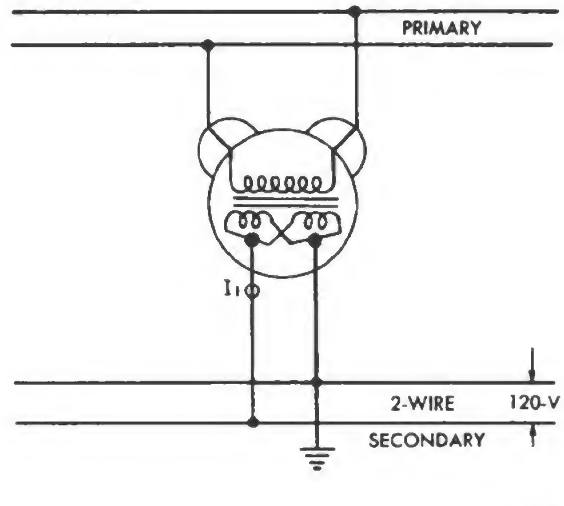
26.85
Figure 6-9.—Attaching open wire services to pole.

raised on to the racks by removing the pin and insulators. This eliminates excessive pole climbing.

After the poles have been properly guyed and the conductors have been dead ended, the conductors are lifted into the grooves of the insulators and tied in. You must remind your crew that on straight lines or inside angles the conductors are placed on the pole side of the insulators; and on the outside angles the conductor is tied in on the outside of the insulator. This is done to keep the strain off the tie wire.

TRANSFORMER CONNECTIONS

The location and size of the transformers are generally determined by standards issued by the Bureau of Yards and Docks, or instructions given by the officer acting as the electrical superintendent. As mentioned earlier, however, you may be called upon to make the decision, and you will be responsible for supervising and instructing your men on the proper procedures for making transformer connections.



26.86
Figure 6-10.—Single-phase connections for small lighting loads.

SINGLE-PHASE CONNECTIONS

In a single-phase connection the transformer is connected as shown in figure 6-10. The 120/240-volt low voltage wirings are connected in parallel. This type of connection will only supply 120 volts.

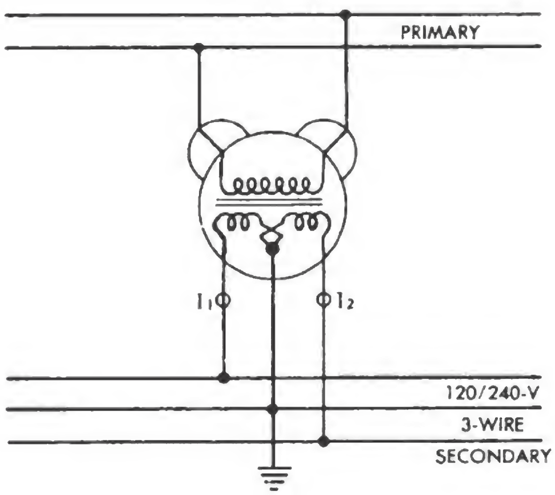
The single-phase connection for light and power shown in figure 6-11 is most commonly used on stations using the delta-delta connection for distribution. The three-phase, (three-wire) system makes possible serving both 120-volt and 240-volt loads simultaneously.

Two single-phase transformers can be used parallel on a single-phase two-wire or three-wire secondary system if the terminals with same relative polarity are connected together. This is not an economical operation because individual cost and losses of the smaller transformers are greater than one larger unit giving the same output; it is included as emergency operations for small transformers. In large transformers, however, operating units in para-transformers, however, operating units in parallel is often practical (as in the network system).

DELTA-DELTA CONNECTIONS

The term delta-delta connection in reference to transformers, means that both the primary and the secondary are connected in delta (fig. 6-12). Note X4 of transformer A ties to X1 of B;

X4 of B ties to X1 of C; X4 of C ties to X1 of A. This forms a series connection of the three-phases; the sum of the voltage within the delta loop is zero. Always make sure it is zero before closing the loop of the secondary by placing a voltmeter, test lamp, or fuse wire between the two ends of the loop. If the lamp lights, or the fuse wire melts, or any other indications of appreciable voltage exist do not close the loop; if you do, you will short circuit the transformer secondaries. This connection is ideal for service continuity as described later in the open delta connection.



26.87

Figure 6-11.—Single-phase connections for light and power.

When both light and power are to be supplied from the same bank of transformers, the mid-tap of the delta secondary of one of the transformers is grounded and connected to the neutral wire of the three-phase secondary system (fig. 6-13). In this case, only one transformer can be used for single-phase loads if the secondaries are to supply three-phase loads at the same time; because with the neutral of one transformer grounded, (fig. 6-14), a ground on either of the other two transformers at any point would cause a short circuit. The lighting-load is then divided between the two current carrying wires of this same transformer, the grounded wire being common to both branches. Closed-delta is used where the power load is more than 60 percent of the total load on the bank.

OPEN-DELTA CONNECTION (POWER)

An open-delta connection for power can be used in an emergency if one of the transformers in a delta-delta bank fails. This type of bank is also used to supply power to a three-phase load which is temporarily light but which is expected to grow. When the load increases to a point where the two transformers in the bank are overloaded, an increase in capacity of 1.73 times the open-delta bank can be obtained by adding another unit of the same size and using the delta-delta connection. The capacity of an open-delta bank is

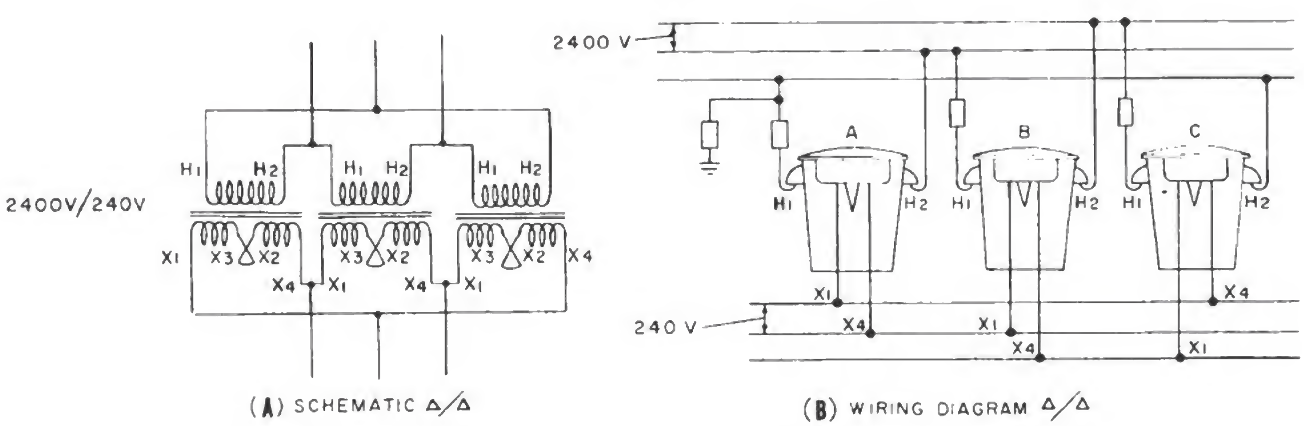


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Figure 6-12.—Delta-Delta transformer connection for three-phase three wire power.

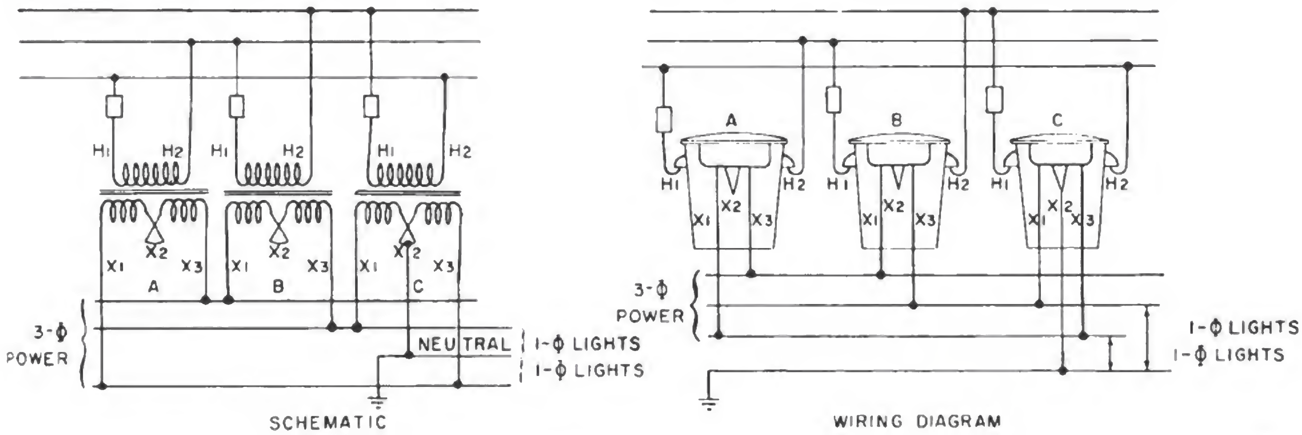

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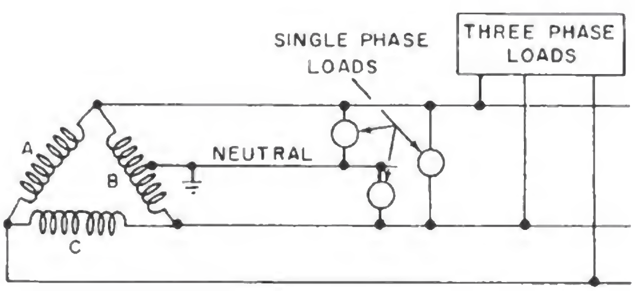
Figure 6-13.—Delta-Delta connections for light and power.



26.90

Figure 6-14.—Three-phase, four wire secondary mains.

only 57.7 percent of a delta-delta (closed) bank of the same size units. Three 25-kva transformers connected delta-delta would have a three-phase capacity of 75-kva; two 25-kva transformers in an open-delta bank would have a three-phase capacity of only 43.3 kva (75 X 577). In an open-delta bank only 86.6 percent of the rated capacity of the two transformers making up the three-phase bank is realized.

When the secondary circuits are to supply both light and power, the open-delta bank is connected as shown in figure 6-15. In addition to the applications mentioned in the preceding paragraph, this type of bank is used where a large single-phase load and only a small three-phase load occurs. In this case, the two-transformers would have different kva sizes, but the same impedance, the one across which the lighting load is connected being the larger.

WYE-DELTA CONNECTIONS

The wye-delta connection (fig. 6-16) is used for light and power where more than 60 percent of the total is power load. If one unit of a wye-delta bank goes bad, service can be maintained by the connection shown in figure 6-17. In regular wye-delta bank with three units, the neutral of the primaries of the transformers is not ordinarily tied in with the neutral of the primary system. This bank can be used even when the primary neutral is not available. In the bank with two units, however, the neutral must be connected as shown in figure 6-17. The main disadvantage of this hook-up is that full-load current flows in the neutral even though the three-phase load may be balanced. In addition to maintaining service in an emergency, this type of bank is satisfactory where the main part of the load is lighting and the three-phase load is small.

DELTA-WYE CONNECTION

In all banks mentioned in the preceding paragraphs for serving light and power on the secondary, the grounded secondary wire is not the neutral of the three-phase system, but rather the midpoint of one leg of the delta. Furthermore, all the lighting load is put on one phase; therefore, the primary currents in any one bank are unbalanced. In the delta-wye connection (fig. 6-18), the neutral of the three-phase secondary system is grounded. The single-phase

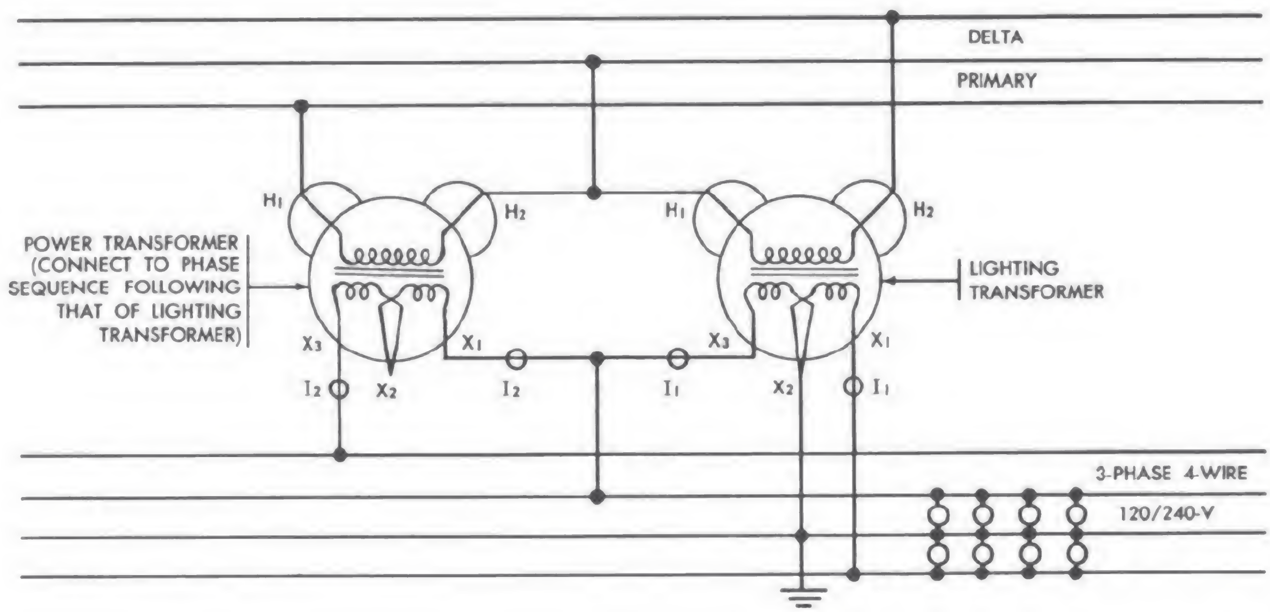


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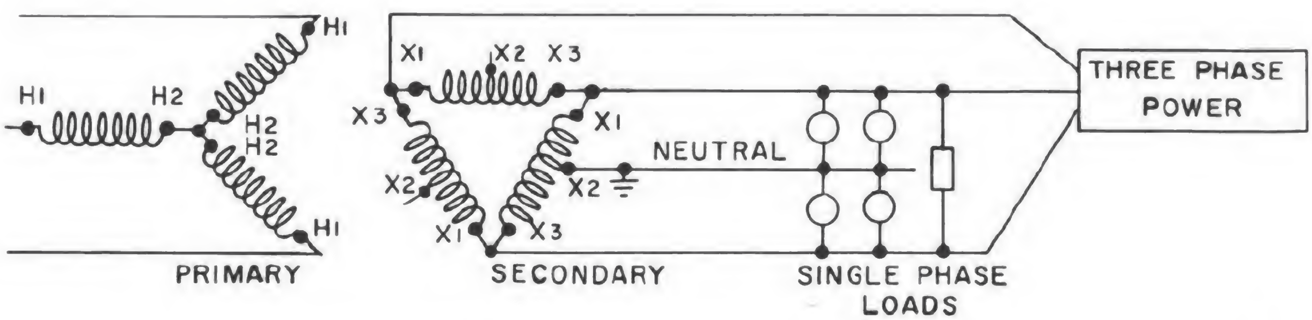
Figure 6-15.—Open-delta bank for light and power.



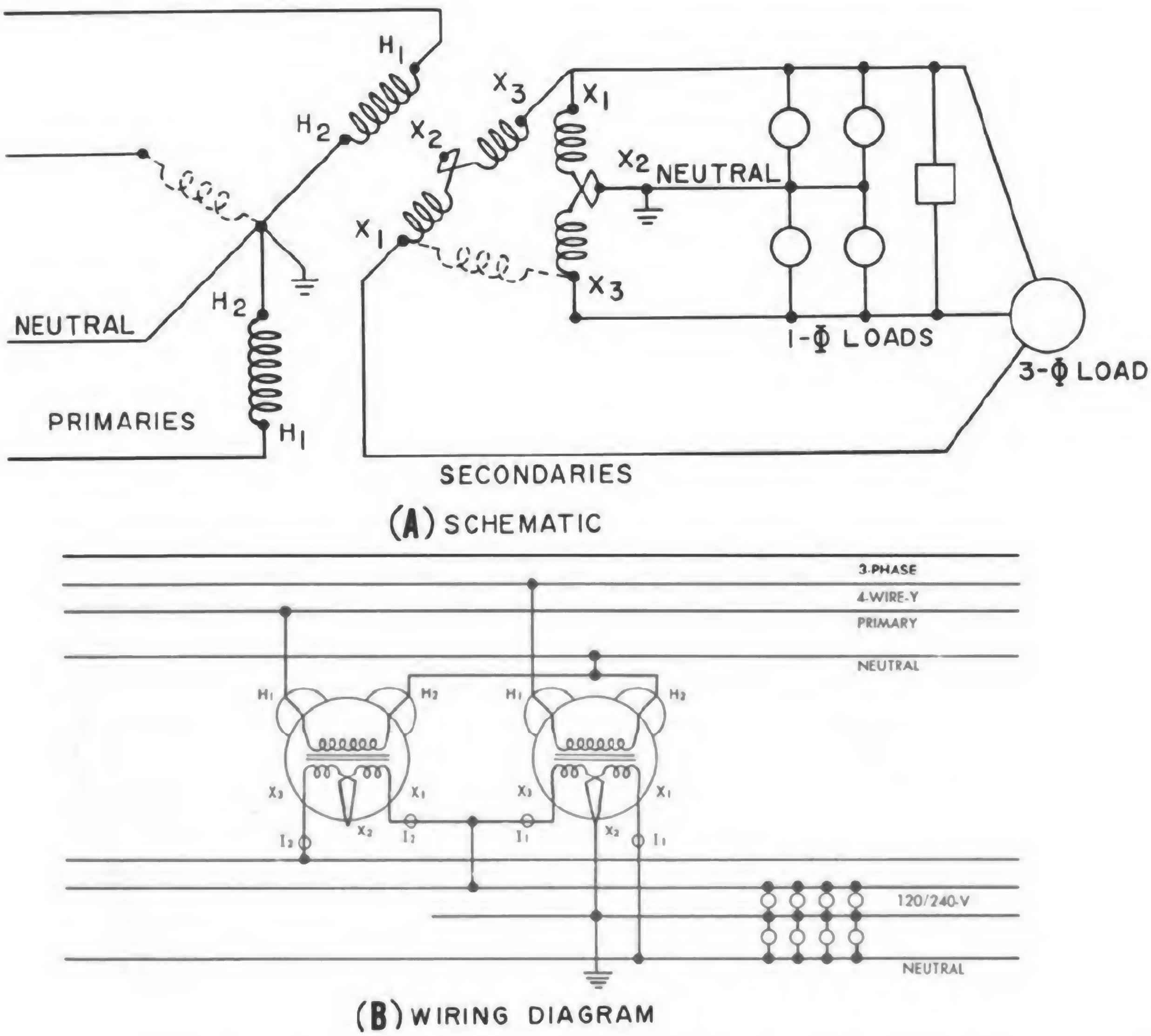
26.92

Figure 6-16.—Wye-delta transformer connections.

loads are connected between the different phase wires and neutral while the three-phase power loads are connected to the three-phase wires. Thus, 120 volts are supplied to the lighting loads and 208 volts to the power load. With this type of bank the single-phase load can be balanced on the three phases in each bank by itself, and the secondaries of different banks can be tied together.

WYE-WYE CONNECTIONS (LIGHT AND POWER)

The primaries of the transformers can also have a wye connection. When the primary system voltage is 2400/4160 wye, 2400-volt transformers would be used in place of 4160-volt transformers that would be required for the delta-wye connection. A saving in transformer cost results. The primary neutral should be available when the wye-wye connection (fig. 6-19) is used, and the neutrals of the primary and secondary systems and of the bank must be tied together. If the three-phase load is unbalanced, part of the load current flows in the primary neutral. Also the third harmonic component (distorted sine waves) of the transformer exciting current flows in the primary neutral. For these reasons, the neutrals must be tied together, otherwise the line to neutral voltage on the secondary would be very unstable. That is, if the load on one phase were heavier than on the



26.93

Figure 6-17.—Wye-delta connection for 120/240 volt, single-phase light and 240-volt, 3-phase power with one unit missing.

other two, the voltage on this phase would drop excessively and the voltage on the other two phases would rise. Also, larger third harmonic voltages would appear between lines and neutral, both in the transformers and in the secondary system, in addition to the 60-cycle component of voltage. For a given value of root-mean-square (rms) voltage, the peak voltage would be much higher than for a pure 60-cycle voltage, and would overstress the insulation both in the transformers and in all apparatus connected to the secondaries.

BOOSTER CONNECTIONS

Booster transformers are used to raise or lower the voltage of the circuit from which the transformer is excited. The primary winding is connected in parallel with the line, and the secondary winding is connected in series with the line. By reversing the secondary connection, its action can be changed from boosting to bucking. The secondary voltage is either added to or subtracted from the primary voltage. The low-voltage winding is subjected to the stresses

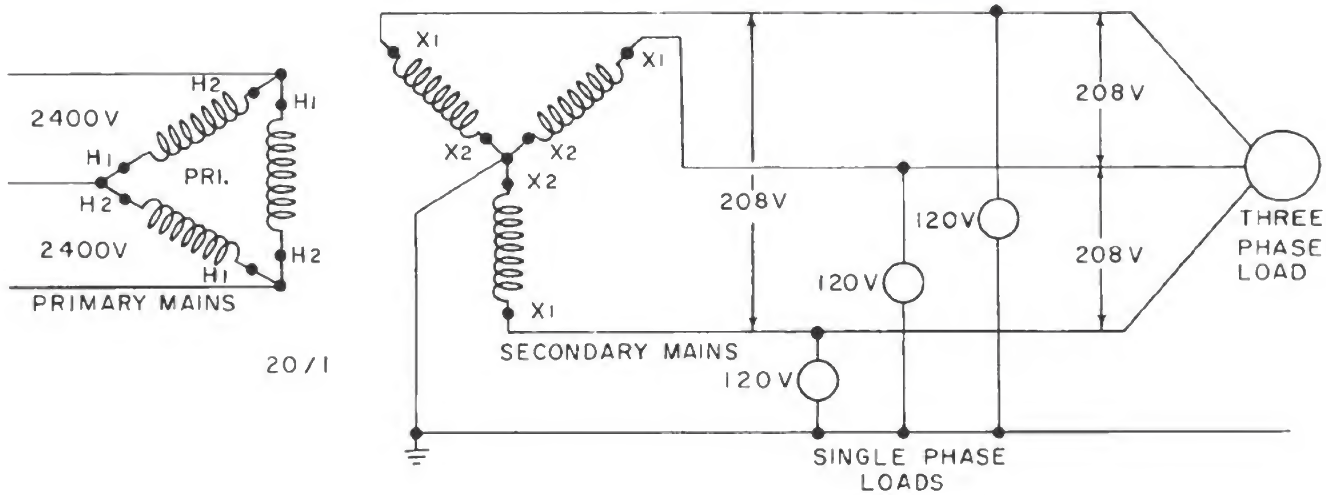


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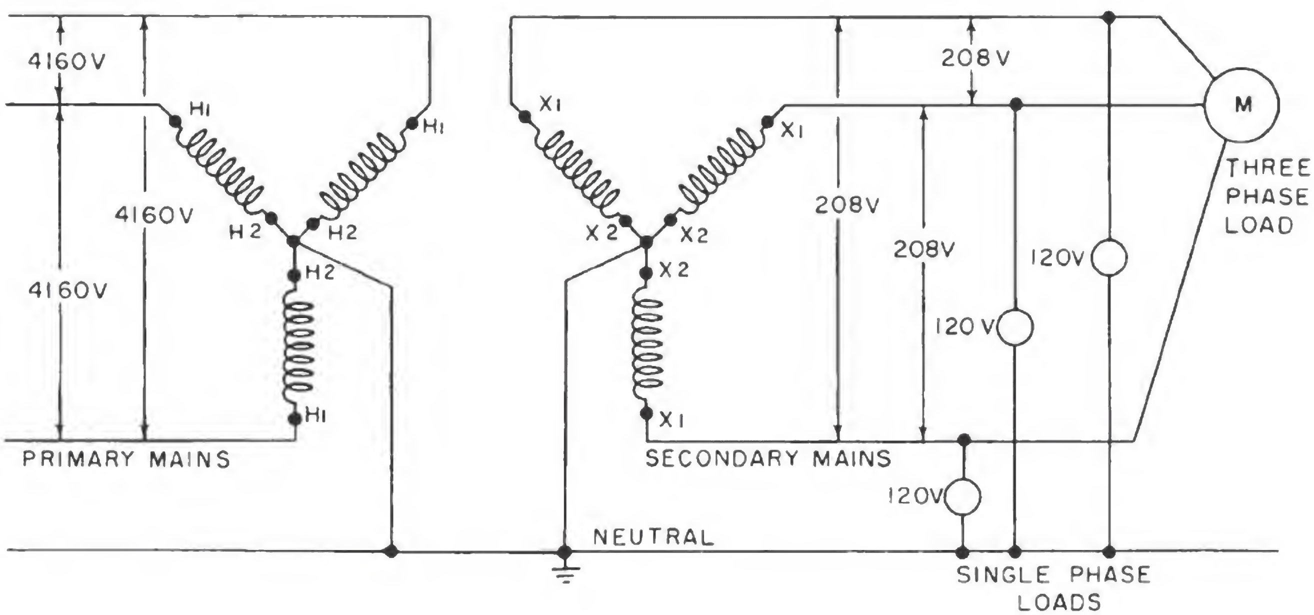
Figure 6-18.—Delta-wye connection.



26.95

Figure 6-19.—Wye-wye connections.

associated with the high-voltage circuit; these stresses must be taken into consideration when using this connection. A booster installation is shown in Figure 6-20.

The percentage of voltage change with the booster connection depends on the ratio of the primary to secondary voltage of the transformer. For example, with a 2400-120/240-volt transformer, using the 240-volt secondary, the ratio is 10 to 1 and the secondary voltage is 10 percent of the primary. With the 120-volt secondary, the ratio is 20 to 1, and the secondary voltage is 5 percent of the primary.

A disadvantage of the booster transformer is that is boosts voltages during the periods of light load; this may result in a primary voltage which is too high during certain times of the day. If the connection of a booster transformer lowers the

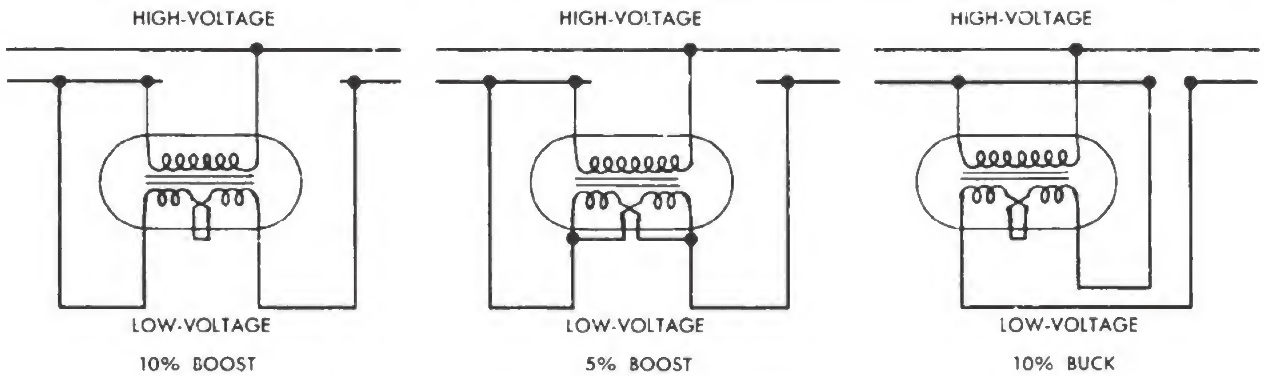


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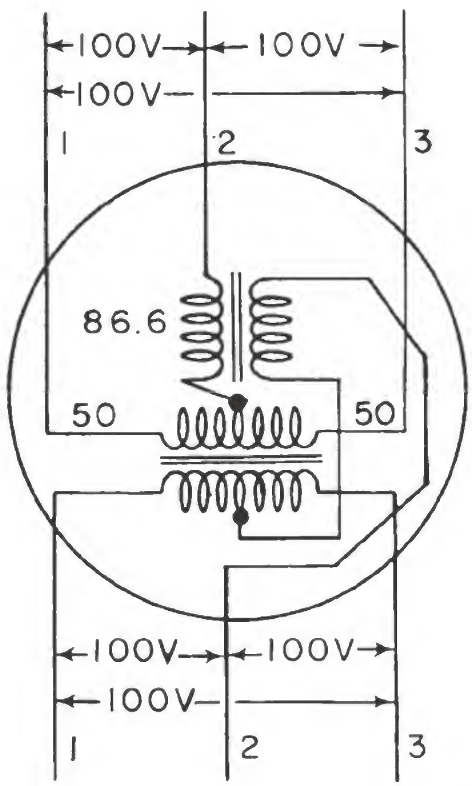
Figure 6-20.—Booster connections.



26.97

Figure 6-21.—T Connection, three-phase to two-phase.

voltage, primary leads are reversed and must be interchanged.

A few suggestions and precautions with respect to booster installations are listed below:

1. When a booster or buck transformer is being disconnected from the circuit, the lead from the secondary winding should be opened first in order to avoid excessive voltage surge.

2. Special booster transformers are available with high-voltage bushings and insulation of the secondary side and are preferred to ordinary distribution transformers for boosting voltage.

3. Booster connections are not recommended for extensive use on station distribution systems because the secondary winding insulation is stressed by the primary voltage. Such an installation is sometimes the only economical solution for a voltage-control problem or when a temporary connection is necessary until a permanent rearrangement can be made.

T CONNECTIONS

Normally you will not use the T connection. However, if you are required to use two transformers to provide three-phase power from a three-phase line you can use the T connection illustrated in figure 6-21. In making this connection note that both windings of one transformer have 50 percent taps, and the other transformer has 86.6 percent taps on both windings.

SCOTT CONNECTIONS

A Scott connection is used to transform two-phase to three-phase power or vice versa. Two transformers are used, a main transformer and a (teaser) transformer. The main transformer has a 50 percent tap on the three-phase side and the teaser transformer has an 86.6 percent tap on the three-phase side (fig. 6-22). The windings are designed so that the three-phase side will carry the full value of three-phase line current; and the two-phase side windings are designed to carry the full value of two-phase line current.

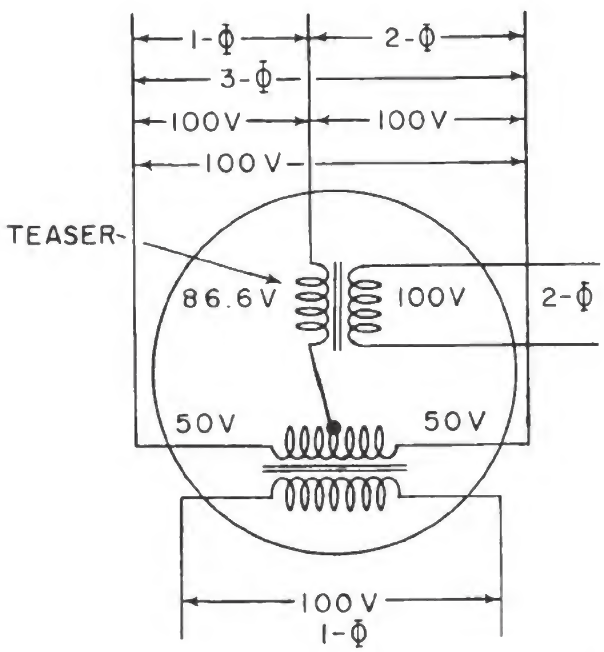


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Figure 6-22.—Scott connection, three-phase to two-phase.

TRANSFORMER INSTALLATION REQUIREMENTS

When a transformer is to be installed it will be up to you to see that the job is done right. That means you should be up to date on the rules and requirements of the electrical code. The code books that cover various electrical requirements are listed in chapter 1. Study the code requirements carefully before installing a transformer. Some of the particularly important transformer installation rules are listed below.

1. One or more transformers may be hung on a single pole if the total weight does not exceed the safe strength of the pole, or crossarms and bolts supporting them.
2. When more than one transformer is installed on crossarms, the weight should be distributed equally on the two sides of the pole.
3. Single-phase transformers of 50 kva or smaller are usually placed ABOVE the secondary mains if conditions permit. Those larger than 50 kva are usually placed BELOW the secondary mains.
4. Lightning arresters and fused cutouts must be installed on the primary side of all distribution transformers except the self-protected type.
5. Ground wires must be covered with a wood moulding to a point 8 feet above the base of the pole.

The rating (size) of the fuse link used in primary cutout is also important. The chart in figure 6-23 will help you pick the correct fuse size. As an example, suppose you have installed a single-phase 75-kva transformer that operates from a 2400 volt primary. Using the chart, first find the transformer capacity (75) on the left side of the chart. Then proceed horizontally to the right until you intersect the primary voltage line (2400 volts). The point of intersection lies in the 100-ampere fuse-link area. Therefore, for this particular installation you would use a 100-ampere fuse.

The size of the training (connecting) wires used to make the connections between the transformer bushings and the primary and secondary mains is also an important consideration. In general, number 6 weatherproof insulated copper wire or equivalent, will prove satisfactory as training wire for the primary connections of transformers, in size up to 200 kva. The size of the secondary training wire, however, will vary with the size of the transformer as shown in table 6-1. In all cases, the secondary training wire should be weatherproof.

Table 6-1.—Proper Size Secondary Training Wire Transformer.

Transformer size (kv.-a.)	Size of outside secondary leads	Size of central or neutral lead
20 or smaller	6	6
25 or 30	4	6
37 1/2 to 50	0	0
75	4/0	0
100	350 MCM	4/0
125	500 MCM	4/0
150 or 200	750 MCM	35 MCM

THREE-PHASE TRANSFORMER BANKS

The total amount of power that can be supplied from three single-phase transformers connected in a three-phase bank is the sum of each transformers kva capacity. Three 25-kva transformers, for example, can be expected to supply 75 kva of power under stated cooling conditions, provided the transformers are approximately equally loaded.

The protective requirements of a three-phase transformer installation are the same as those of a single-phase service. That is, a lightning arrester and fused-cutout are connected to each phase wire of the primary main feeding the transformer. The size of the fuse, again, is determined by the total capacity of the transformer bank and the value of the primary voltage. The chart in figure 6-24 will help you select the proper size fuse.

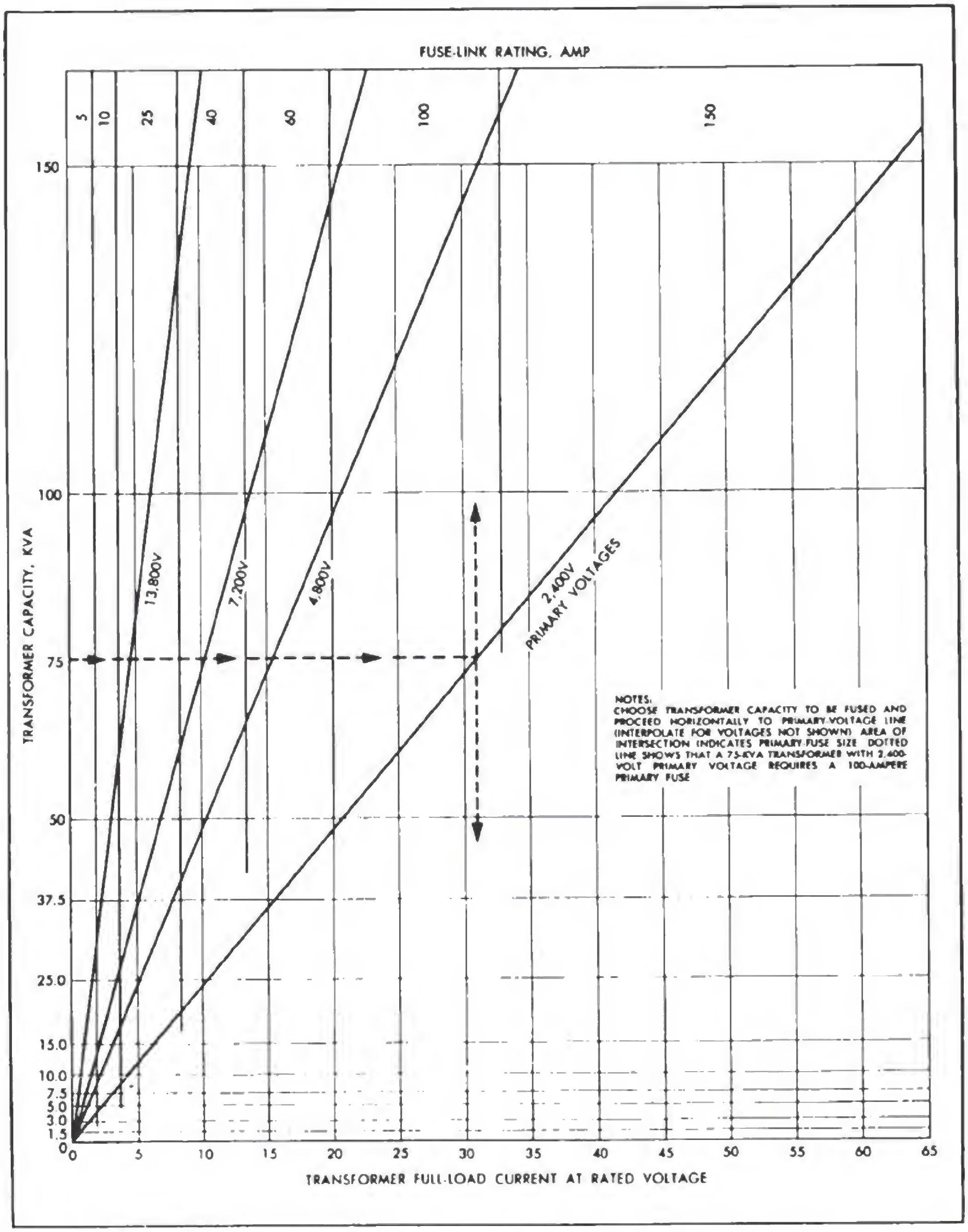

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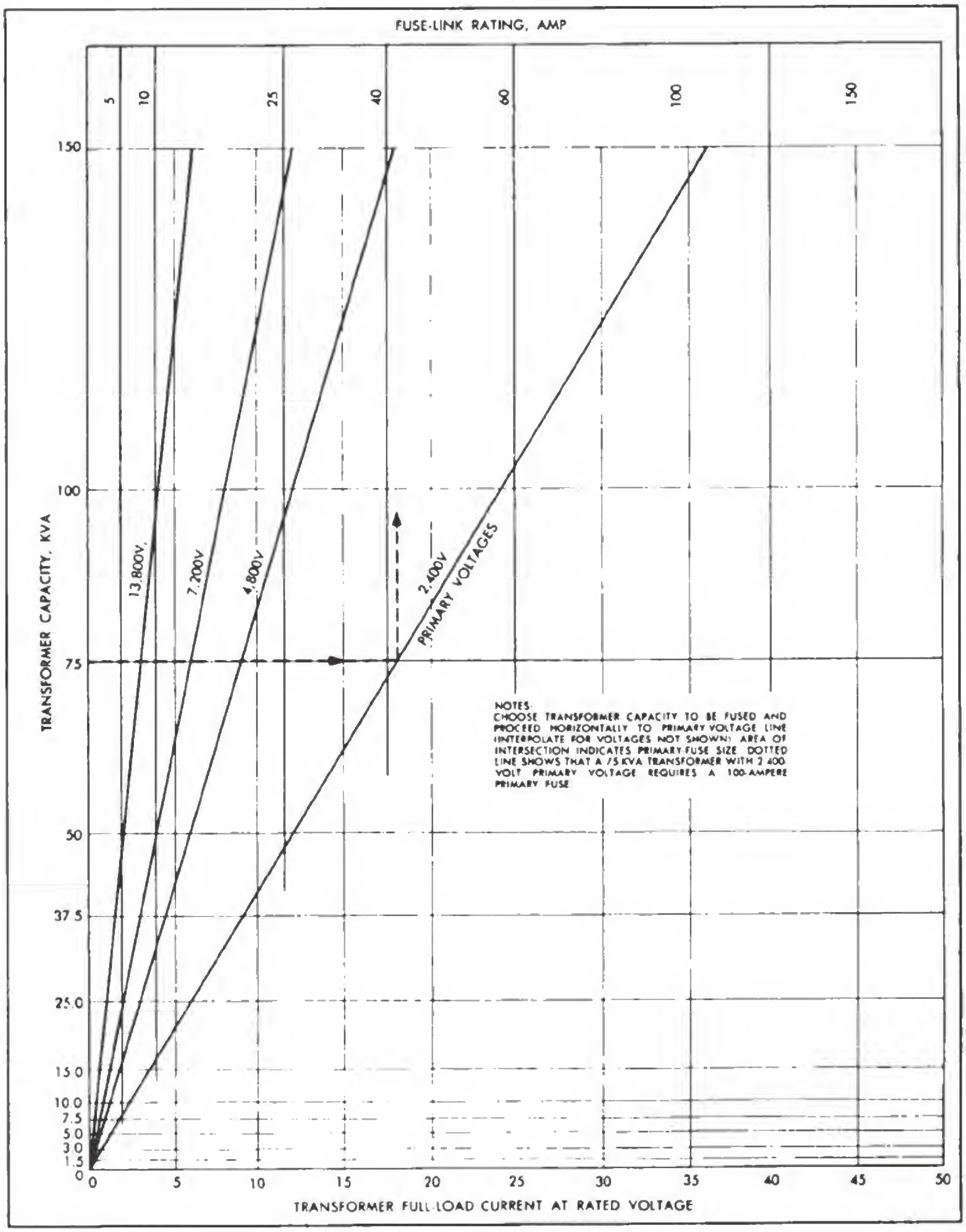
Figure 6-23.—Fuse size for single-phase installation.



26.100

Figure 6-24.—Fuse size for three-phase installation.

Pole Installation

Three single-phase transformers may be mounted on a single pole for a three-phase installation. The transformers can be secured directly to the pole if equipped with mounting lugs (pole brackets) or hung on a double crossarm if equipped with hangers.

Figure 6-25 gives an overall view of a typical three-phase installation using three single-phase transformers. The construction features of this installation are typical of those found in other three-phase services mounted on one pole. Notice the method of supporting the transformers. The main support consists of double crossarm mounted approximately 4 feet below

the primary main. Notice that a kicker-arm is installed just below the double crossarm. The kicker arm provides a support for the bottom of the transformer hanger and thus maintains the transformer in a rigid vertical position.

Figure 6-25 shows a closeup of lightning arrester connections and construction. Although only two arresters are visible, there is another mounted on the other end of the crossarm and connected to the third phase of the line. The arresters are clamped in a hanger mounted flat against the side of the crossarm that supports the primary main. A wire from the top of each arrester is connected by means of a solderless connector to a phase wire. Notice the drip-loop in the wire. A ground wire leads from the bottom of each arrester and connects to the main ground wire that is stapled to the underside of the crossarm.

Figures 6-6 and 6-26 show how the primary fuse cutouts are mounted on the double crossarm by means of a cutout hanger. The fuses shown are a combination of disconnect switch and fuse. When the hinged cover is pulled down in the position shown, the training wire circuit leading to the primary bushing is opened. When the hinged cover is closed, the fuse is automatically inserted in the circuit.

Platform Installation

When the combined weight of the transformers cannot be safely handled by one pole, you should have the transformers placed on a platform supported between two poles. Except for the difference in construction, the general principles of connecting the transformers and the protective equipment requirements apply equally to this type installation and to the pole-mounted type.

The three-phase transformer bank illustrated in figure 6-27 is a typical example of a platform-mounted installation. Both a front and side view are shown and the physical dimensions and electrical requirements are indicated. The platform's foundation is built of two 4-inch by 8-inch creosoted timbers mounted between the poles and bolted on each end to a pair of 4- by 8-inch creosoted crossarms. Two by fours, spaced 1 inch apart, serve as the floor of the platform. There will be occasions when the dimensions of the timber which you need cannot always be met by the stock you have on hand. But they should be matched as closely as possible. It is not necessary to bolt the transformers to the platform; their weight will be great enough to keep them in place.

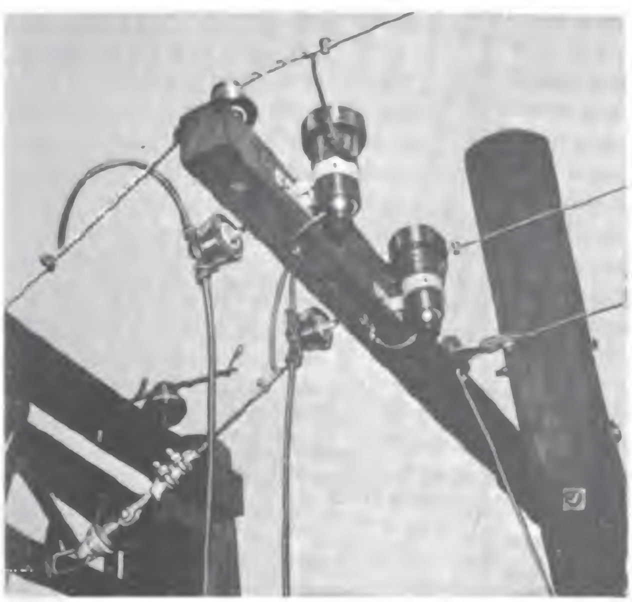


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Figure 6-25.—Lightning arrester connections.

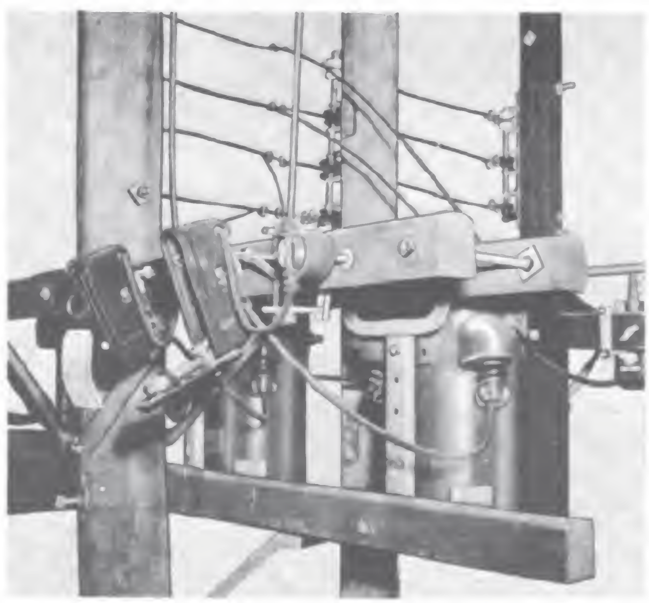

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Figure 6-26.—Primary fuse cutout connections.

In the installation shown in figure 6-27 the transformer bank is placed at the end of the primary main run. Therefore, it is necessary to use a pole-to-pole guy and pole-to-ground guy to counteract the pull of the wires. The three lightning arresters clamped to the top crossarm are connected to the primary main and to a ground wire on the side of the pole. Training wires tapped to each primary main drop down and connect through fuse cutouts to a three-wire primary bus stretched between poles. The secondary bus is also mounted between the poles but above the primary bus.

The transformer bank is connected with a delta primary and a delta secondary. A four-wire secondary main for light and power is obtained by mid-tapping the secondary of one of the transformers.

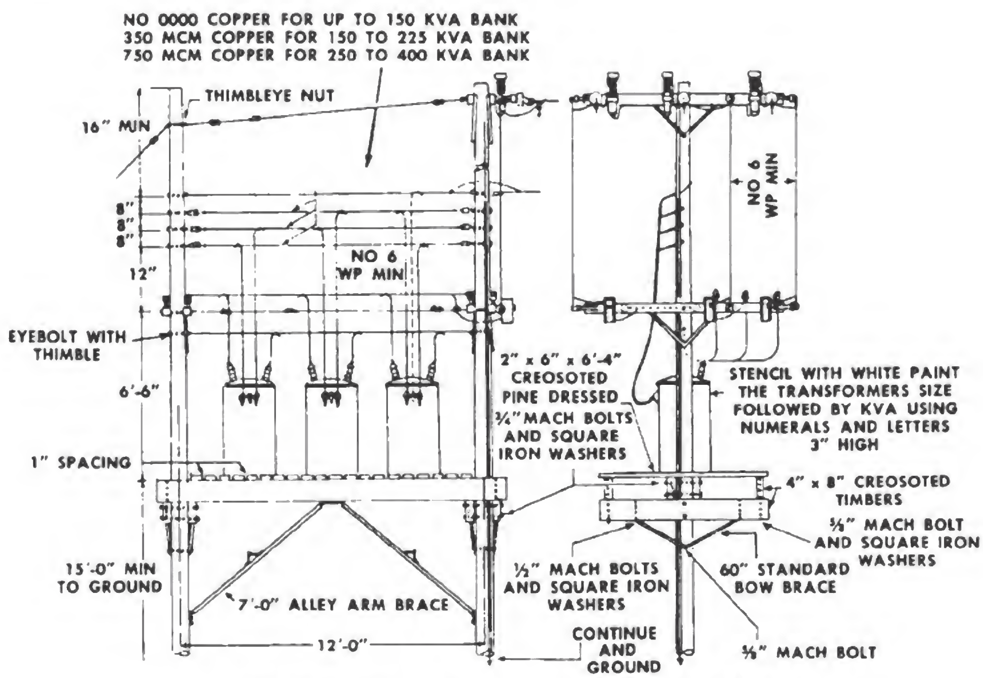
Ground Installation (Bank)

The larger single-phase transformers when connected into a three-phase bank must be directly on the ground. This situation will arise in some substation installations. You may also find it necessary to install transformers on ground if two three-phase banks are needed to supply power to the same area or building. Aside from the special construction features necessary to mount a transformer on the ground, there are only two major safety requirements which make a ground bank installation different from a pole or platform mounted bank. First, in addition to the normal grounding of neutral wires and lightning arresters, all equipment and steel work must be effectively and permanently grounded. Second, a protective fence must be built around the installation with warning signs prominently displayed.

TRANSFORMER MAINTENANCE AND REPAIR

The largest part of your transformer maintenance and repair will be concerned with the inspection and replacement of defective bushings, the inspection and replacement of insulating oil, and the reconditioning of leads.

Transformer installations should be inspected at regular periods. In addition, you should instruct your crew to keep an eye open for any indications of transformer failures during daily work routine.



Note. Three transformers may be from 25 to 100 KVA. Delta Secondary.

26.103

Figure 6-27.—Platform mounted three-phase transformer bank.

CHAPTER 7
WIRE COMMUNICATION

Communication facilities at advance bases are far less elaborate than facilities at permanent bases located in the United States. The equipment is rugged and as compact and portable as possible.

The most common type of telephone equipment used at advance bases includes the SB-22/PT switchboard, telephone central office set TC-2, TC-4, and the TC-10. Other communication equipment normally found at advance bases are interoffice communication equipment, and public address systems.

As the Construction Electrician first class or chief, it is your responsibility to see that the above mentioned communication equipment is properly installed and maintained.

SB-22/PT SWITCHBOARD

The SB-22/PT, is a 12-line, portable, local-battery switchboard. It is designed to establish a working telephone system for units up to and including the size of a battalion. The front and rear view of the 12-line switchboard is shown in figure 7-1 A and B.

The SB-22/PT is a small, lightweight, immersion-proof switchboard used for interconnecting local-battery lines. It requires no special mounting equipment for operation. The names of the main parts are given in figure 7-1 A and B. The components which comprise the SB-22/PT are shown in figure 7-2 and 7-3.

The SB-22/PT switchboard is also equipped for remote control radio communication. Under normal conditions your crew needs to be concerned only with the telephone lines. The procedure for connecting the wires of the switchboard to a radio circuit is very similar to the procedure for making connections to the telephone circuit.

LINE PACKS

The 12-line packs are located on the left side of the front panel. A line pack is shown in figure 7-3. Each line pack is fastened to the switchboard by two captive screws, one at the top of the unit, the other at the bottom. The line pack consists of a reel unit, a drop, a jack, and an identification strip.

The REEL UNIT consists of a reel, a cord, and a plug. The cord is fastened to the spring-loaded reel by three screws at one end and is equipped with a standard switchboard plug at the other end. The cord may be extended to a maximum distance of 35 inches and is retracted by the spring-loaded reel.

The DROP consists of an electromagnet and a hemispherical piece of metal with a luminous strip painted horizontally across it. When a telephone user turns the crank of the hand generator serving the telephone, a circuit is completed, causing the hemispherical piece to rotate downward; this exposes the luminous strip. The drop is restored by a mechanical linkage between the drop and the jack.

The JACK is used in conjunction with the cord of the operator's pack, or with cords of the line pack, to interconnect line circuits.

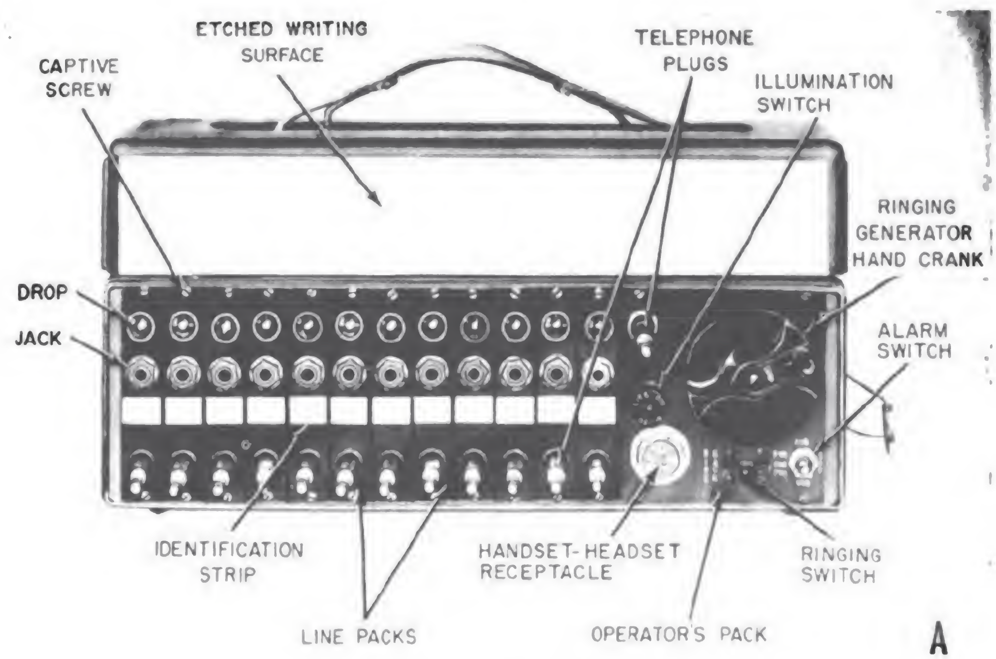
The IDENTIFICATION STRIP is a piece of white plastic fastened beneath the line jack. Marks on this strip identify the telephone circuit associated with the line pack.

OPERATOR'S PACK

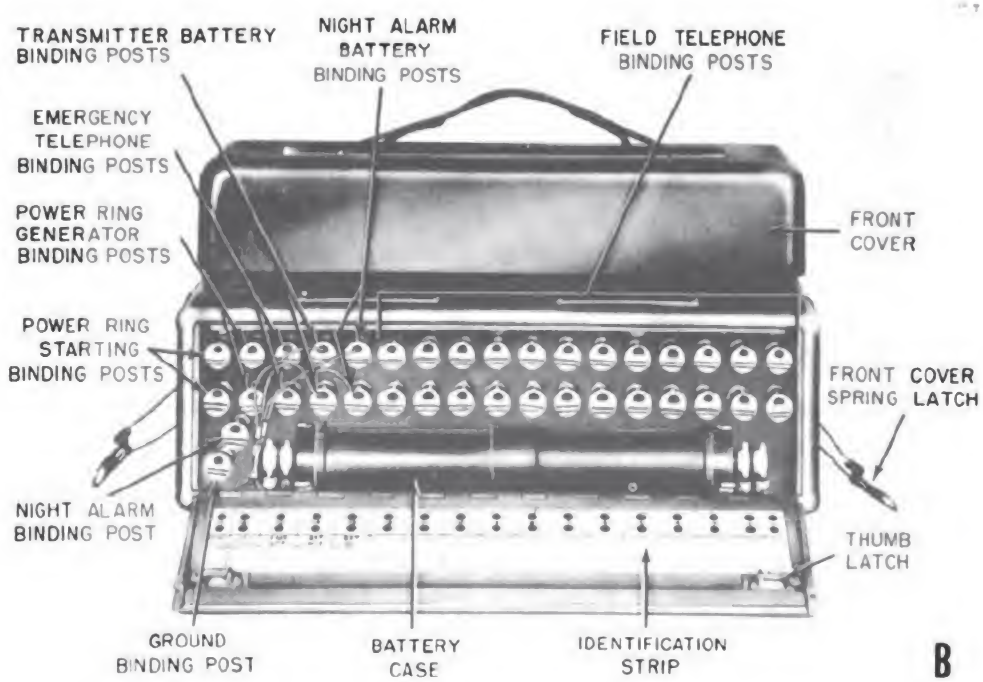
The OPERATOR'S PACK (fig. 7-4) is located on the right of the front panel. The pack consists of a reel unit, ringing equipment, alarm equipment, and a handset-headset receptacle.

The REEL UNIT is identical to that of the line pack. The ringing equipment consists of a hand generator and a control switch. Ringing current is generated when the hand crank is rotated. The control switch has two positions: RING BACK and PWR RING FWD. This switch enables the operator to connect ringing current to the calling or to the called telephone.

The ALARM EQUIPMENT provides a more positive signal for the operator than that afforded by the drop mechanism of the line pack. The



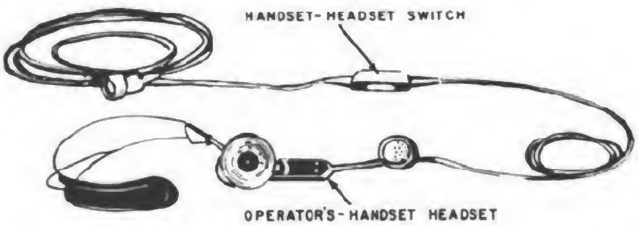
A. Front view



B. Rear view

Figure 7-1.—Twelve-line switchboard, SB-22/PT.

26.104



26.104.3
Figure 7-2.—Manual telephone switchboard SB-22/PT, components.

alarm equipment consists of the signaling buzzer and a lamp. When the switchboard is signaled by an outlying telephone, the drop on the line pack associated with the outlying field telephone falls; this completes a circuit through the alarm lamp or the buzzer depending on the setting of the switch. Either the lamp lights or the buzzer sounds.

The HANDSET-HEADSET receptacle is a polarized, bayonet-locking, 10-conductor receptacle which is used with the plug on the handset-headset cord.

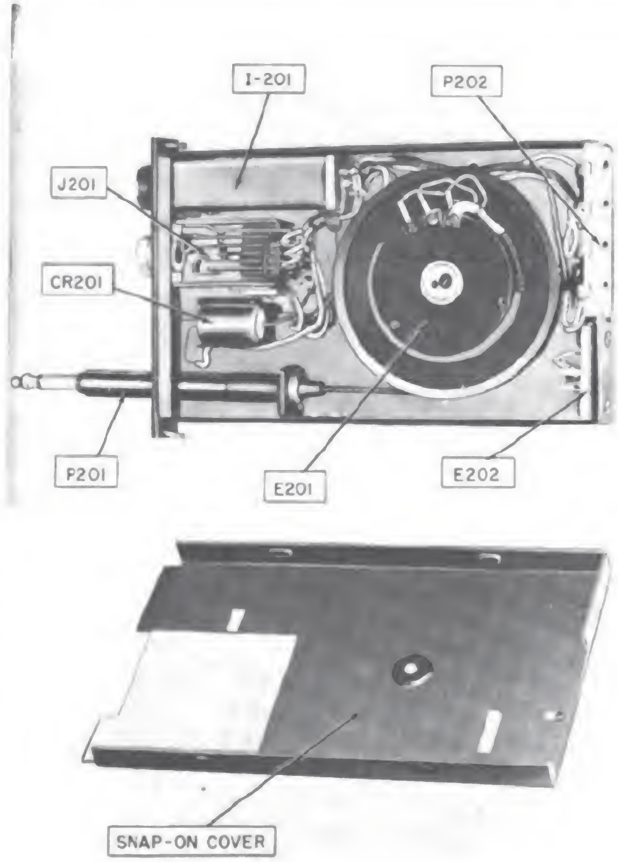
PREINSTALLATION PROCEDURES AND CHECKS

You should inform your crew that the 12-line switchboard may be placed in any convenient location. They should place it on a surface of the proper height to ensure ease of operation. If a suitable stand is not immediately available, they may temporarily place it on the ground.

Your crew should be careful not to damage the equipment during uncrating and unpacking. You should have it inspected immediately upon unpacking for possible damage during shipment. The original packing cases and containers should be saved, so they can be used again when the equipment is repacked for storage or shipment.

Before the connections are made, instruct your crew on the proper procedures for testing the line and operator's packs.

After the connections are made and the tests have been completed, direct someone to talk over the line and note the quality of transmission. If transmission is poor or speech cannot be heard at normal speech level, check the wiring and repeat the tests. If the trouble continues, replace the operator's pack.

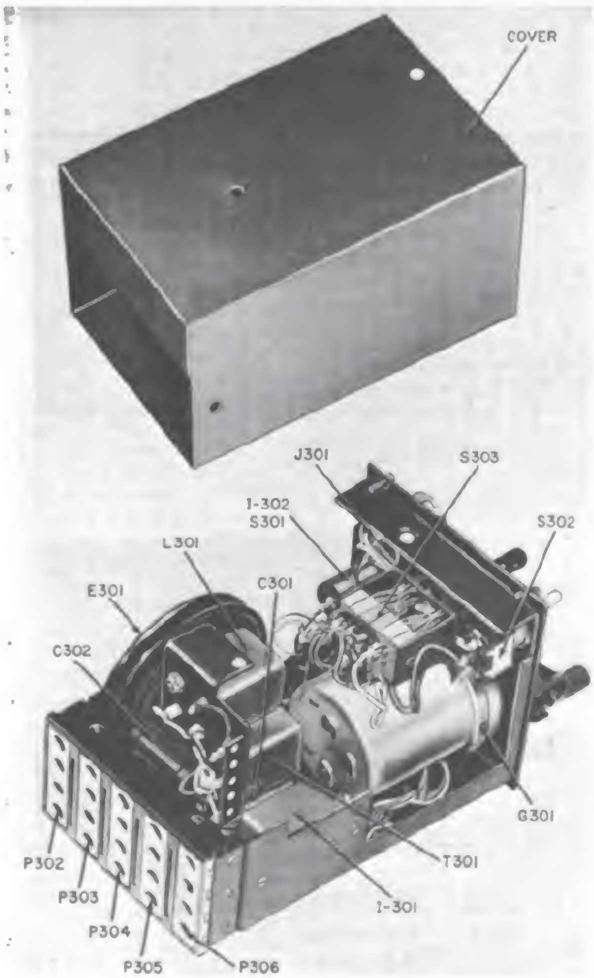


I-201	Switchboard signal
J201	Telephone jack
CR201	Selenium rectifier
P201	Cord assembly
E201	Reel unit
E202	Lightning arrestor
P202	Clip assembly

26.105
Figure 7-3.—Line pack for SB-22/PT switchboard.

INSTALLATION PROCEDURES

Your crew should make the ground connection before connecting the wire lines to the switchboard. You should select the lowest, dampest site in the vicinity; clay or loamy soil is best. You should have one of your crew members scoop out a hole 6 inches deep and drive a ground rod into the hole until the top of the rod is about 3 inches below the undisturbed ground surface. Have him connect



P302 P303 P304 P305 P306	Clip assembly
I-301	Night alarm buzzer
T301	Induction coil
G301	Ringing Generator
S302	Night alarm switch
S303	Lever switch (ringing)
J301	Receptacle connector
I-302	Night lamp
S301	Signal lamp switch
C301	Coupling capacitor
L301	Retardation coil
E301	Reel unit
C301	Coupling capacitor

26.106

Figure 7-4.—Operator's pack for SB-22/PT switchboard.

one end of the wire to the ground rod. The earth around the rod should be saturated with water, and the hole filled with earth. The other end of the wire should be connected to the binding post located on the frame behind the rear access door.

To connect the wire lines to the switchboard, a pair of binding posts should be selected and connected to the desired circuit. Be sure to record the circuit identification on the proper identification strip.

When the wire lines are connected, you are ready to install the four dry-cell batteries, which furnish the power. Remove the battery case and insert the two BA-30 batteries into the compartment so that the brass contact end of each battery faces outward. Repeat the procedure for the compartment at the other end of the battery case. After completing this operation, replace the case into the spring retaining clips.

STACKING OF TWO SWITCHBOARDS

To serve more than 12 but fewer than 30 lines, you can have your crew stack two 12-line switchboards. Have the operator's pack removed from the switchboard and install five line packs in the empty space. This modified switchboard should be placed on top of a normally equipped switchboard. It is necessary to use two jumpers to connect the two switchboards. One jumper must be connected to the NA binding posts of both switchboards, and the other jumper must be connected to the GNP binding posts of both switchboards. Be sure that your men pass the jumpers through the slot at the side of each switchboard. Only one set of batteries is required to serve both switchboards; the battery case from the one containing the 17 line packs (from which the operator's pack has been removed) should be removed. The field telephones can then be connected as previously described. A maximum of 29 lines can be served with this arrangement.

MAINTENANCE AND REPAIR

See that your crew makes frequent inspections of the equipment to keep it in good working order. Dust, dirt, grease, or moisture should not be allowed on the exterior of the switchboard

or the handset-headset. The crew should use a clean, dry, lint-free cloth or a dry brush for cleaning. The electrical contacts on the frame of the switchboard should be cleaned with a cloth moistened with dry-cleaning solvent, and should be wiped dry with a clean dry cloth. A burnishing tool should be used to clean the switch contacts.

Rust, fungus, dirt, and moisture tend to accumulate on the binding posts, plugs, and external portions of the line jacks. Have these removed with a dry rag or brush. The battery case and clip contacts should be inspected for corrosion, moisture, fungus, and tightness. All lines should be checked for kinks, strains, moisture, fungus, and loose terminals; also have the insulation checked to see that it is not frayed, cut, or otherwise damaged.

Moving parts of the SB-22/PT do not require lubrication. When necessary, see that one of the crew members lubricates the spring latches of the front cover, and the thumb latches and hinge of the rear access door.

Failure of the switchboard to operate properly is usually caused by one or more of the following:

1. Rundown batteries
2. Defective operator's handset-headset
3. Defective line pack
4. Defective operator's pack

Rundown batteries may be indicated by any of these difficulties:

1. Pull switch is pulled out, but lamp fails to light.
2. Drop of a line pack indicates that a telephone is signaling the switchboard, but the lamp or buzzer of the operator's alarm fails to work.
3. The operator cannot talk to any of the telephone users.

Remove rundown batteries, and replace them in the manner previously described.

A defective handset-headset prevents the operator from talking to any of the telephone users, from receiving calls from any of the outlying phones, or both. Replace defective handset with one that is in working order.

A defective line pack may be indicated by any of the following troubles:

1. The user of a telephone cannot signal the operator because the drop does not function.
2. The drop of a line pack for a particular telephone works, but the operator's alarm fails to function. (If this difficulty occurs with all telephones, the trouble may be rundown batteries or a defective operator's pack.)
3. The operator cannot talk to or receive calls from the user of a telephone.
4. The users of two telephones cannot converse with each other, but the operator can converse with each user separately.

The line pack is a self-contained, plug-in unit. It may be removed by loosening the two captive screws from the front panel, inserting the plug into the jack, and pulling on the plug until the line pack is free from the front panel. The replacement should then be reinserted into the empty space. After the captive screws are tightened, the new line pack is ready for operation.

A defective operator's pack may be indicated by any of the following difficulties:

1. Lamp fails to light when a pull switch is pulled out (also may be caused by burned-out lamp or rundown batteries).
2. The operator's alarm fails to work when the drop of a line pack indicates that a telephone is signaling the switchboard (may also be caused by rundown batteries).
3. The operator cannot ring any field telephone.
4. The operator cannot talk to any telephone users (may also be caused by a defective handset-headset or rundown batteries).
5. The operator cannot receive calls from telephones on the line (may also be caused by a defective handset-headset).
6. The operator cannot ring back.

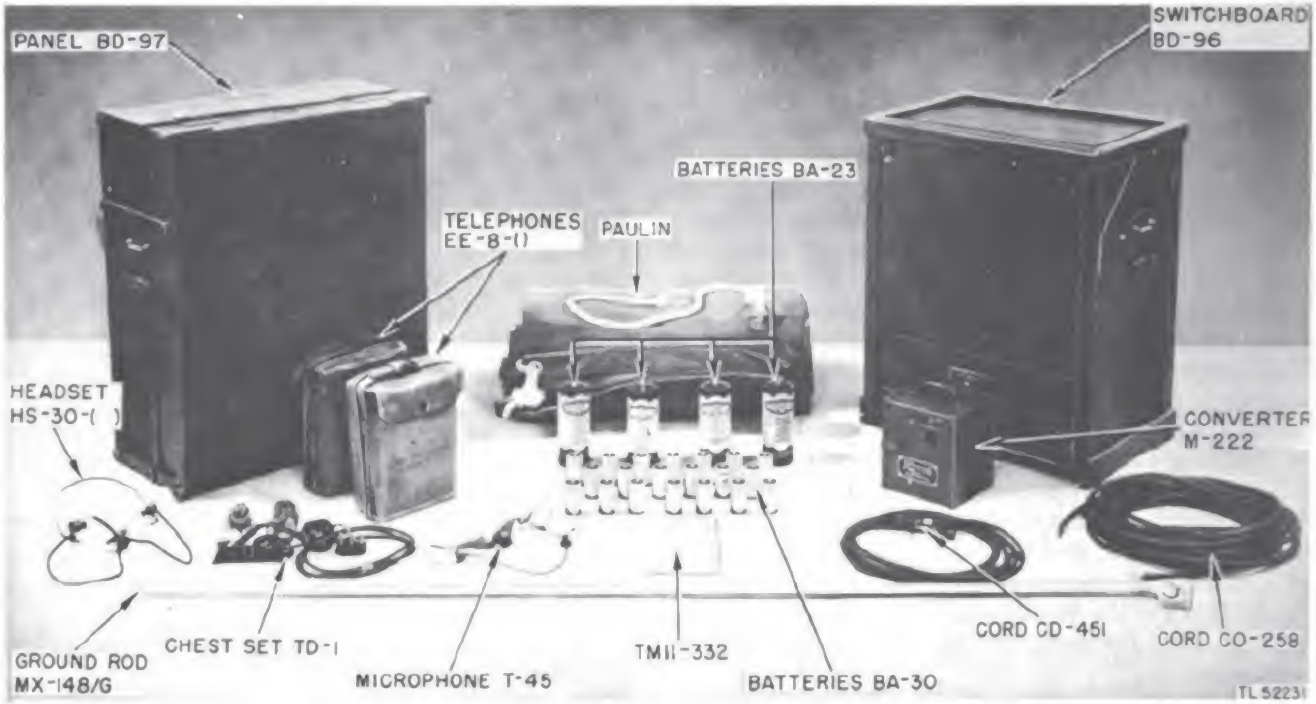
If at all possible you should always have handy a circuit wiring diagram and exploded views of the various parts of the SB-22/PT switchboard in order to make emergency repairs if spare parts are not available.

TELEPHONE CENTRAL OFFICE SET TC-4

The telephone central office set TC-4 is a transportable switching central consisting of a main distribution frame (MDF), telephone switchboard, and accessories. It is designed for use at division or other headquarters which require a switchboard with 40 line circuits (switchboard BD-96). The telephone central office set TC-4 and its components are shown in figure 7-5.

SWITCHBOARD BD-96

Switchboard BD-96 is a complete, transportable, single position, manually operated



26.107

Figure 7-5.—Components of telephone central office set TC-4.

telephone switchboard. Trunk circuits are provided which may be used for connection to common battery lines of either manual or automatic central offices. Drop signals are provided for the lines and trunks and are associated with each cord for recall signals. A compartment is provided in the rear of the switchboard for connection of batteries to supply current for talking and for the night-alarm buzzer. The top of the switchboard contains terminal facilities for ringing current, grouping, a second operator, and external battery.

Switchboard BD-96 contains the following circuits:

- 1 First operator's telephone circuit and grouping key
- 12 Cord circuits
- 1 Ringing circuit
- 40 Line circuits, magneto
- 4 Trunk circuits, common battery, manual or dial
- 1 1 Dial-cord circuit
- 1 Conference circuit
- 1 Night-alarm circuit
- 1 Second operator's telephone circuit

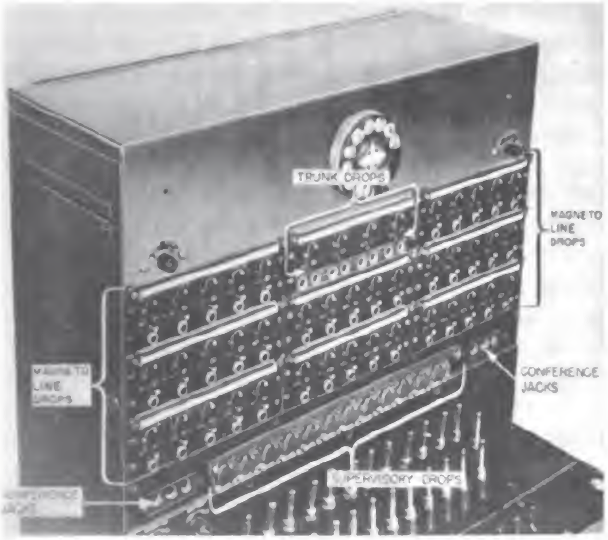
Line Jacks and Drops

Forty magneto line drops and four dial and manual common battery trunk drops with associated jacks are located on the face of the switchboard (fig. 7-6). The magneto line drops are self-restoring; the trunk drops must be manually restored. The drops provided for the four trunk circuits are numbered 35 through 38 and are located in the center of the top row of drops. Each trunk drop has a double jack which provides for dialing.

Binding Post Panel

The line jacks are wired to a binding post panel in the top of the switchboard which provides for connections with spade-terminal strips through rubber-jacketed cable to panel BD-97. The binding post panel contains 90 binding posts in three parallel rows of 30 binding posts per row.

Other accessories on the switchboard BD-96 are the 12 SUPERVISORY DROPS located on the



26.108
Figure 7-6.—Switchboard BD-96, front view.

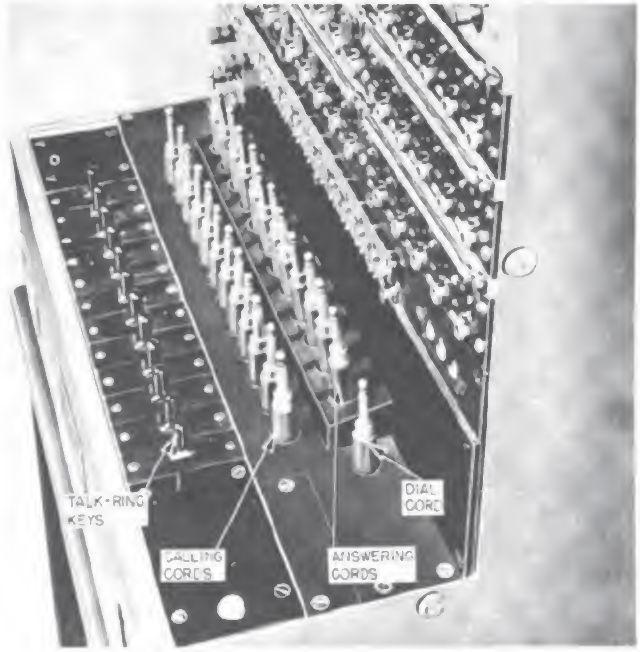
bottom row of the switchboard face (fig. 7-6). These drops are manually restored. There are also 3 CONFERENCE JACKS located to the left and 3 to the right of the supervisory drops. The conference jacks are interconnected so that a six-party conference circuit may be set up on the switchboard. And finally, there are the CORDS and TALK-RING KEYS. The 12 calling cords, 12 answering cords, 1 dial cord, and 12 talk-ring keys are located on the keyshelf of the switchboard. (See fig. 7-7.) Adjacent keys, cords, and supervisory drops are connected internally.

PANEL BD-97

Panel BD-97 is the main distributing frame unit for use with switchboard BD-96. Arrangement of the apparatus is shown in figure 7-8. An opening with a sliding cover is provided for incoming line wires in each side of the panel. An opening with a sliding cover is also provided in the bottom of the upper cabinet for the cables to the switchboard when the cabinet door is closed. Eight repeating coils, four on each side, are mounted on the protectors.

Cables

The cabling between the panel and the switchboard consists of three rubber-jacketed

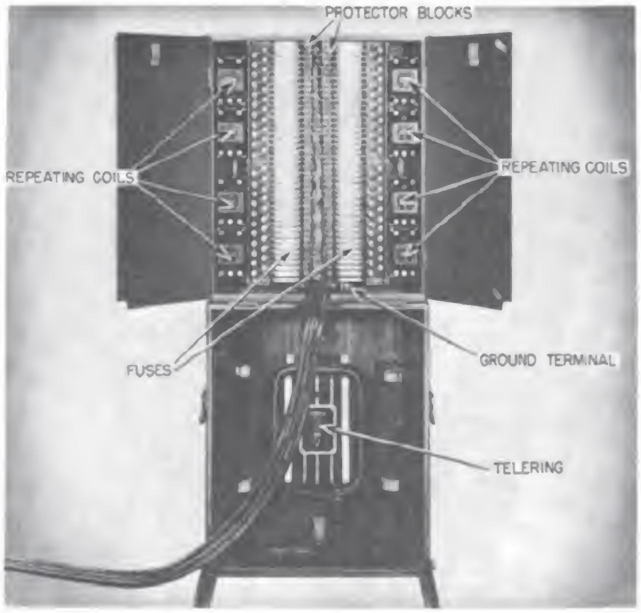


26.109
Figure 7-7.—Switchboard BD-96, keyshelf equipment.

cables each containing 15 pairs of braid-covered latex insulated, No. 22 AWG (American wire gage) stranded conductors. The cables, exclusive of the cable connectors, are 21 feet in length. The cable is connected at the panel directly to the fuses. At the switchboard end the cables are terminated in cable connectors which consist of strips of insulating material between which is mounted a row of 30 spade terminals. These terminals are mounted to allow some movement so that they will be self-aligning when connections are made to the binding posts on the switchboard terminal panel. The cable conductors are soldered to these spade terminals. The soldered connections are enclosed in a copper-alloy protecting cover.

Fuses and Protector Blocks

Two vertical rows of 22 pairs of 1-ampere fuses and protector blocks (unit dischargers) are mounted in the panel. Two terminal strips, each with 44 binding posts, are mounted to each side of the panel for connecting the incoming line wires. These terminals are permanently wired to the line side of the fuses and protector blocks.



26.110
Figure 7-8.—Panel BD-97 set up, front view.

Telering

The telering is mounted in the lower cabinet of panel BD-97 and is used as a source of ringing power when 110 volt, 60-cycle a-c power is available.

INSTALLATION OF TELEPHONE SET TC-4

Before you have your crew install the TC-4 telephone set, you should decide upon the general layout in view of the local conditions. The equipment is partially weatherproofed and the tarpaulin which is provided can be used as a fly or tent, making it possible for the equipment to function outdoors in almost any kind of weather. Select the driest location available and one that is suitable for a good GROUND connection. In selecting the site you should consider the operator. Make sure that the location is as far from extreme noise as practicable so the operator will not be disturbed. Another consideration should be the lighting arrangement. Arrange the equipment so that a subdued light will shine on the operator's work rather than shining in the operator's eyes.

It is not necessary to set up the panel next to the switchboard. In fact, for inside installations, the panel may be placed in another room. The maximum distance between panel and switchboard is limited to approximately 20 feet by the length of the connecting cables. Always place the panel far enough from the switchboard to allow free movement about the panel.

In setting up the switchboard BD-96, your men should make sure that the base is level; and see that they install six batteries BA-30 in the compartment in the lower back of the switchboard as illustrated in figure 7-9.

After the switchboard is set up, have a thorough inspection made for damaged or loose parts.

Setting Up Panel BD-97

In supervising the installation of the panel BD-97 you should see that it is set up properly with the hinged edge up, and within cabling distance of the switchboard.

You should then locate a good ground source, such as a water pipe or other buried metallic object of good conductivity having a large area of earth contact. If this is not available drive a ground rod deeply into moist earth. Use light strokes to prevent whipping of the rod from destroying the earth contact. Tamp the soil firmly down around the rod. If additional conductivity is required a second ground rod of the same type may be driven at least 10 feet away from the first rod and the two connected in parallel. Moistening the surrounding ground with salt water will improve ground conductivity.

26.111
Figure 7-9.—Installation of batteries in rear compartment of switchboard.

Converter

Converter M-222 or the M-222A are designed to supply emergency power ringing current for telephone switchboards such as switchboards BD-91 and BD-96, when power from a 110-volt, 60-cycle source is not available or when the standard 110-volt power ringing equipment fails in service. Converter M-222 or M-222A is a standard component of telephone central office sets TC-4 and TC-12. Figure 7-10 shows converter M-222 and M-222A.

The converter M-222A is housed in a rectangular steel box with two removable sides, which permits easy access to all circuit components by merely unscrewing four captive screws and removing the right cover. Two spring clips are mounted on the inside of the left cover to hold batteries in place.

Installation of Batteries

Two batteries BA-23, (1-1/2 volt-dry cell) are required for operation of converter M-222 or M-222A.

In installing the batteries be sure that your men properly connect the 2 batteries in series using the battery connector. They should connect the green wire which is grounded to the case of the converter to the vacant positive terminal of the two batteries, and the red wire should be connected to the vacant negative terminal. Be sure that the batteries are placed in the battery compartment with the terminals facing the fiber insulator.

Connection of Converter

To connect the converter for use, plug the power ringing cord from the switchboard into the output receptacle. On converter M-222, the receptacle is located on the front of the converter. On the M-222A, the receptacle is located on the right cover. After the connection is made throw the switch to the ON position to start the converter.

CAUTION: When the converter is not in use, always throw the switch to the OFF position to prevent batteries from being discharged.

PREVENTIVE MAINTENANCE

Although the converter has a small number of component parts, routine preventive maintenance is required for various reasons. For

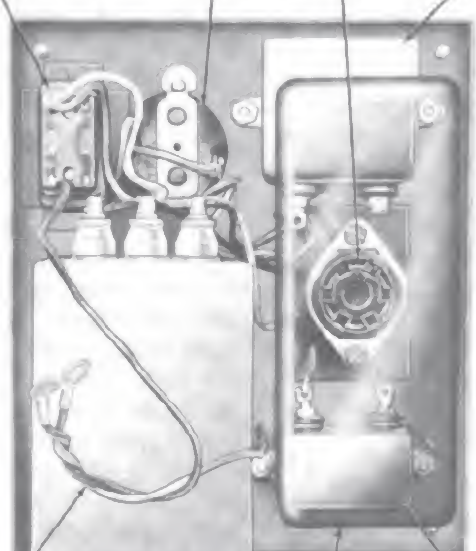


Figure 7-10.—Converter M-222A, right cover removed.

example, dust encountered on dirt roads during cross-country travel filters into the equipment no matter how much care is taken to prevent it. Rapid changes in weather (such as heavy rain followed by sunshine and high temperatures), excessive dampness, snow, and ice tend to cause corroision of exposed surfaces and parts. Without frequent inspections and the necessary tightening and cleaning operations, equipment becomes undependable and may break down when it is most needed.

Inspection is the most important operation in the preventive maintenance program. A careless observer will overlook the evidences of minor trouble. Although these defects may not interfere with the performance of the equipment, valuable time and effort can be saved if they are corrected before they lead to major breakdowns. Make every effort to have your crew become thoroughly familiar with the indications of normal functioning so that they will readily recognize the signs of a defective set. Have them check for the following conditions:

1. Overheating, as indicated by discoloration, blistering, or bulging of the parts or surface of the container; leakage of insulating compounds; oxidation of metal contact surfaces.
2. Placement, by observing that all leads and cabling are in their proper positions.
3. Cleanliness, by carefully examining all recesses in the unit for accumulation of dust, excessive moisture, and so on, especially between connecting terminals. Parts, connections, and joints should be free of dust, corrosion, and other foreign matter. In tropical and high-humidity locations, look for fungus growth and mildew.
4. Tightness, by testing any connection or mounting which appears to be loose.

CAUTION: Do not tighten screws, bolts, and nuts carelessly. Fittings tightened beyond the pressure for which they are designed will be damaged or broken. Whenever a loose connection is tightened, moistureproof and fungiproof it again by applying varnish with a small brush.

CONNECTING THE TC-4 COMPONENTS

All connections between components of telephone central office set TC-4 are shown in the cording diagram in figure 7-11 and are connected as follows: (Not necessarily in this order.)

1. Connect all three panel cables to top compartment of the switchboard. Match the numbers marked on the cable terminals with the numbers marked at each end of the terminal strips in the top of switchboard BD-96. Tighten all screws with the proper size screwdriver.
2. Connect the ground terminal in panel BD-97 to the ground rod.
3. Connect the incoming lines to the binding posts in the upper cabinet of panel BD-97. Arrange the lines neatly and out of the way to minimize trouble and facilitate troubleshooting. All connections should be made firm and the loose ends of wires trimmed in order to eliminate the possibility of short circuits.
4. Plug the cord of the telering into a convenient 110-volt, 60-cycle outlet. (If none is available use the converter M-222 or M-222A mentioned earlier.) Extend ringing current to switchboard BD-96 by means of cord CD-451.
5. After all other connections have been made, connect headset HS-30 and the necessary chest set.

PERFORMANCE CHECKLIST

As crew chief you should have available a performance checklist similar to the one shown in table 7-1, to help the operator to determine whether telephone set is functioning properly. In looking over table 7-1 you will note that items 1 to 6 are checked before starting, items 7 to 13 when starting, and items 14 through 16 during operation. Items 14 through 16 should be checked continuously during the normal operating period.

The normal indications listed in table 7-1 include the visible and audible signs that the operator will receive when he checks the items. If the indications are not normal, the operator should apply the recommended corrective measures.

The corrective measures listed are those that the operator can make without turning the equipment in for repairs.

TELEPHONE CENTRAL OFFICE SET TC-2

Telephone central office set TC-2 is equipped with a 57-line switchboard. This switchboard consists of 20 magneto (local-battery) lines and 37 common-battery lines. A switchboard of this type is designed for a base where the majority

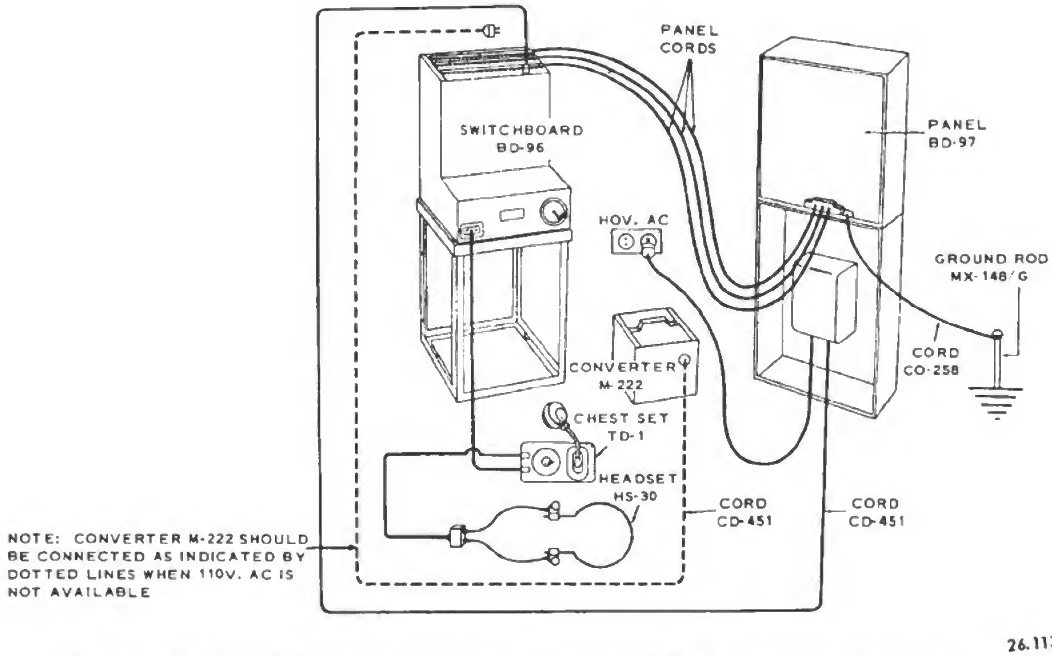


Figure 7-11.—Telephone central office set TC-4, cording diagram.

of telephones are in a centrally located area, but where a few telephones are located in outlying activities. Telephones located a considerable distance from the exchange require local-battery operation.

The complete switching system consists of the 57-line switchboard, a main distributing frame (MDF), a power panel, a rectifier, a power unit, and necessary accessories.

The switchboard is the Army Signal Corps-type BD-89. It is a portable, single-position, two-panel, manually operated type. In addition to the 57 telephone lines, it contains three trunklines which may be connected to other switchboards. One trunk circuit provides for two-way service between the switchboard and a dial central office. A dial cord circuit is provided for dialing on the trunk circuit. Lamp signals are provided for the common battery lines and the cord circuits.

Drop signals are provided for the magneto lines, with magneto recall lamps associated with each cord circuit. The line jacks are wired to a terminal strip at the rear of the switchboard which provides for connections with spade terminal strips through rubber-jacketed cables to the main distribution frame. Terminal facilities are provided for making connections to the storage battery supply (24 volts DC), ringing current supply, and grouping key circuit. One model of the BD-89 switchboard is shown in figure 7-12.

MAIN DISTRIBUTING FRAME

The main distributing frame serves to terminate the outside lines and to connect them to the proper line jacks on the switchboard. Cabinet BE-79 (fig. 7-13) is the MDF used with the BD-89 switchboard. The MDF is equipped with protector blocks and heat coils which are connected to terminal strips. Binding posts are provided for the incoming lines and for cross-connecting, so that all such connections can be made without soldering. There are twelve repeating coils mounted on the line side of the MDF to permit cross-connection and cabling.

The line side of the cabinet contains two vertical strips of protectors, each strip consisting of 40 pairs of protector blocks and heat coils. The heat coils guard against the cumulative effects of small currents that might produce excessive heat when they flow for considerable periods of time. A terminal panel equipped with 80 binding posts for connecting the incoming

Table 7-1.—Equipment Performance Check List.

	Item No.	Item	Action or Condition	Normal Indications	Corrective Measures
PREPARATORY	1	Panel cables	Connected to three rows of binding posts in top of switchboard BD-96.		
	2	Panel binding posts	Incoming lines connected.		
	3	Ground Rod MX-148/G	Installed and connected to ground terminal of panel BD-97.		
	4	Batteries BA-30	Six batteries installed in rear of switchboard BD-96.		
	5	Telering	Connected to a-c outlet, if available. Also connected to switchboard BD-96.		
	6	Converter M-222	Connected to switchboard BD-96 if 110-volt, 60-cycle, a-c power is not available.		
	7	Chest Set	Plug into switchboard BD-96.		
START	8	NIGHT ALARM key	Move to ON position for audible signal.		
			Move to OFF position when audible signal is not desired.		
	9	GROUPING key	Move to OFF position for single switchboard operation.		
			Move to ON position if two switchboards are grouped together.		
	10	OPERATOR 1-2 key	Move to 1 position for single switchboard operator.		
			Move to 2 position for two switchboard operators.		
	11	RINGING HAND-KEY key	Move to HAND for hand generator ringing.		
			Move to KEY for power ringing.		
	12	BATTERY 1-2 key	Move to 1 position for operation on first set of transmitter batteries.		
			Move to 2 position for operation on second (spare) set of transmitter batteries installed in rear compartment of switchboard.		
	13	EXT. BAT. key	Move to OFF position for normal operation.		
			Move to ON position if external battery is connected to binding posts in top of switchboard.		
EQUIPMENT PERFORMANCE	14	Magneto line and night-alarm circuits	Distant station rings into switchboard.	Drop shutter falls.	
			NIGHT ALARM key in ON position.	Buzzer operates.	Check batteries.
			Insert answering plug into line jack.	Shutter is restored to normal position.	
	15	Cord and first operator's telephone circuit	Operate TALK-RING key to TALK.	Conversation is possible between operator and distant station.	Check batteries.
	16	Ringing and supervisory circuits.	Insert calling cord into desired line jack and operate TALK-RING key to RING. (RINGING key in KEY position.) If using hand generator (RINGING key in HAND position), crank the hand generator.	Bell of called station rings and station answers.	Check ringing source and connections from power ringing equipment.
			Distant station rings back.	Supervisory drop falls.	

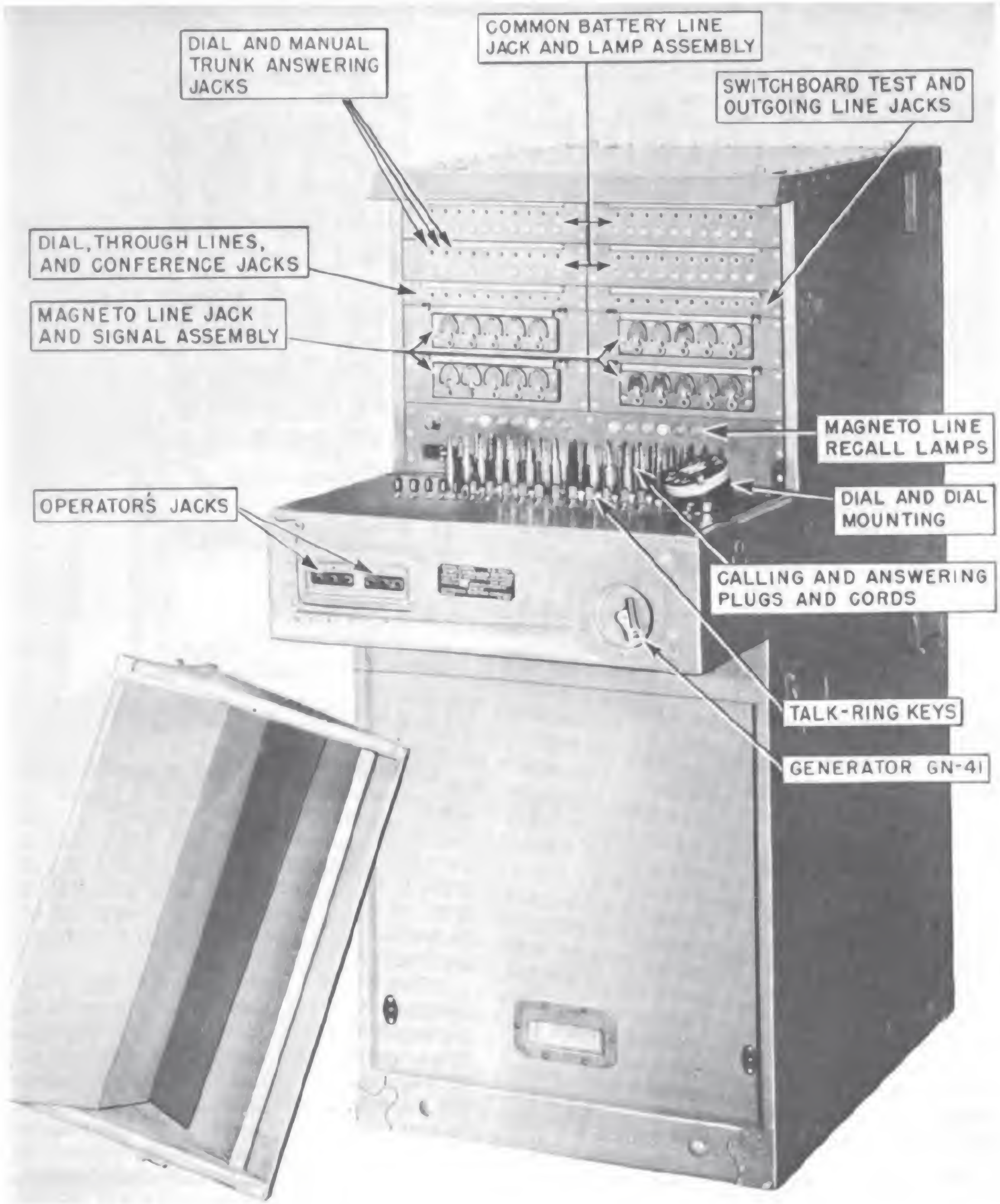
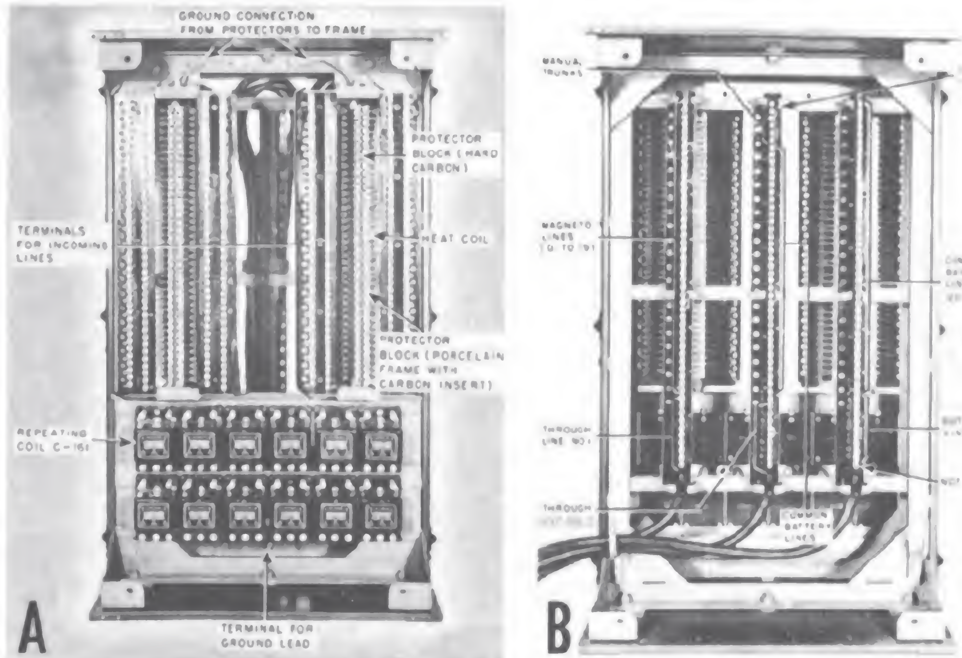


Figure 7-12.—Switchboard, BD-89C. 26.114



A. Line side
B. Switchboard side

24.115

Figure 7-13.—Cabinet BE-79, main distributing frame.

lines is mounted on the line side of the protectors. The central office side of the protectors is permanently wired to a terminal panel equipped with 80 binding posts from which the lines may be cross-connected to the switchboard cable connector binding post terminals or repeat coils.

The switchboard side has three cable connectors. Each connector consists of a strip of insulating material equipped with a row of 50 binding post terminals (25 pairs) to which the switchboard cable conductors are soldered. The cables, exclusive of cable connectors, are 21 feet long. Each cable connector at the switchboard end of the cable is made up of two strips of insulating material between which is mounted a row of 50 spade terminals, so mounted that some movement is allowed.

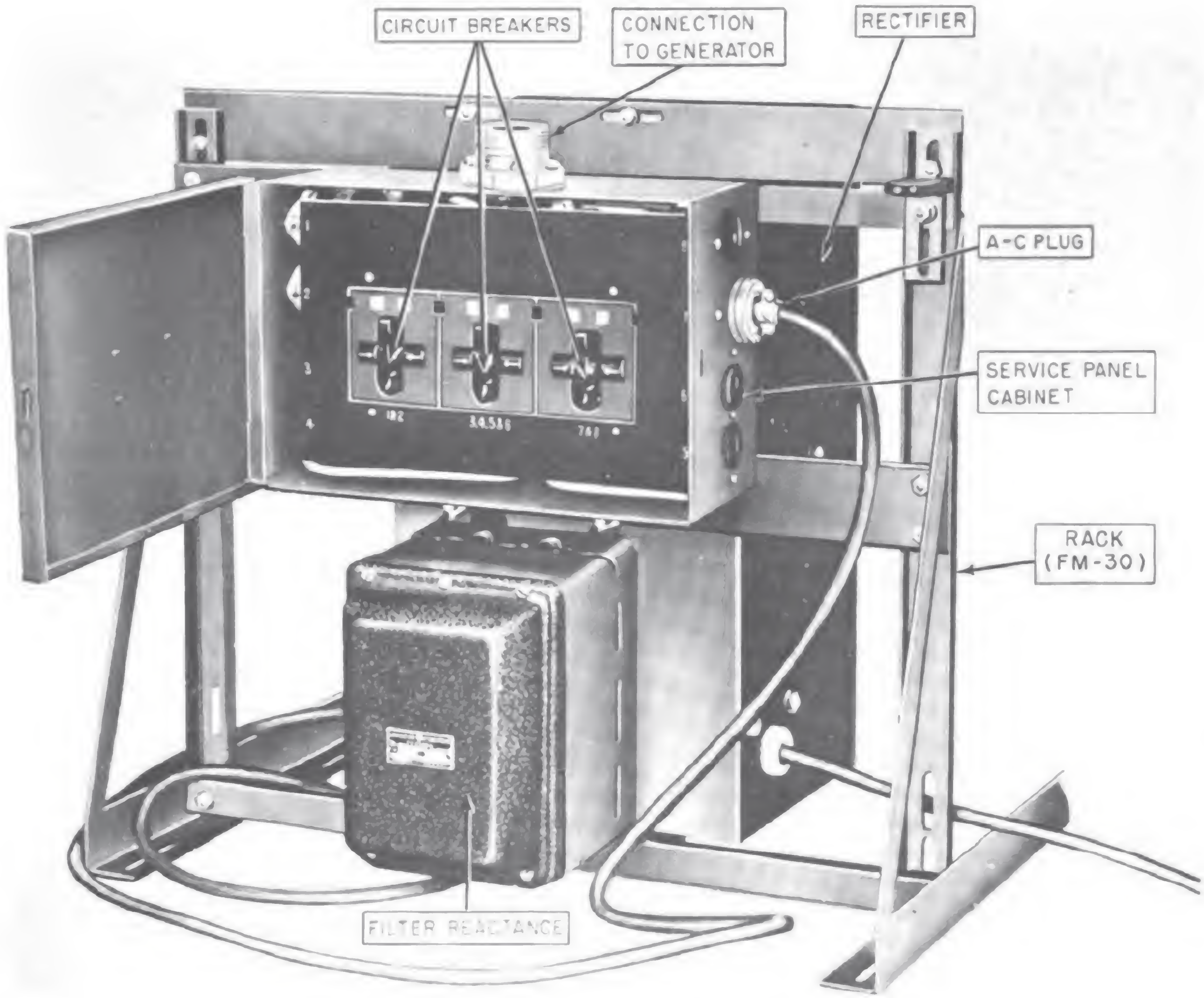
The 12 coils on the coil rack are mounted directly below the protectors in two horizontal rows of six coils per row. Each coil is mounted separately to simplify removal if replacement is required.

OTHER AUXILIARY EQUIPMENT

Other auxiliary equipment necessary to operate the switchboard includes a power service panel, power unit, junction box, accessories (headset, chestset, ground rods, and cords) rectifier, storage batteries, and a power distribution or control panel. The latter serves both to control the rate of charge of storage batteries and to provide ringing current to the switchboard.

The power service panel (fig. 7-14) is designated cabinet BE-75. In figure 7-14, it is mounted on a rack, along with a rectifier and filter reactance. Cabinet BE-75 contains two sockets and two outlets for the connections of the rectifier and the other power cords. Three circuit breakers control the current to the sockets.

The power unit will most likely be a gasoline engine driven a-c generating set designed to generate 120-volt, single-phase, 60-cycle current. The power unit is used only if another source of power is not readily available.



26.116

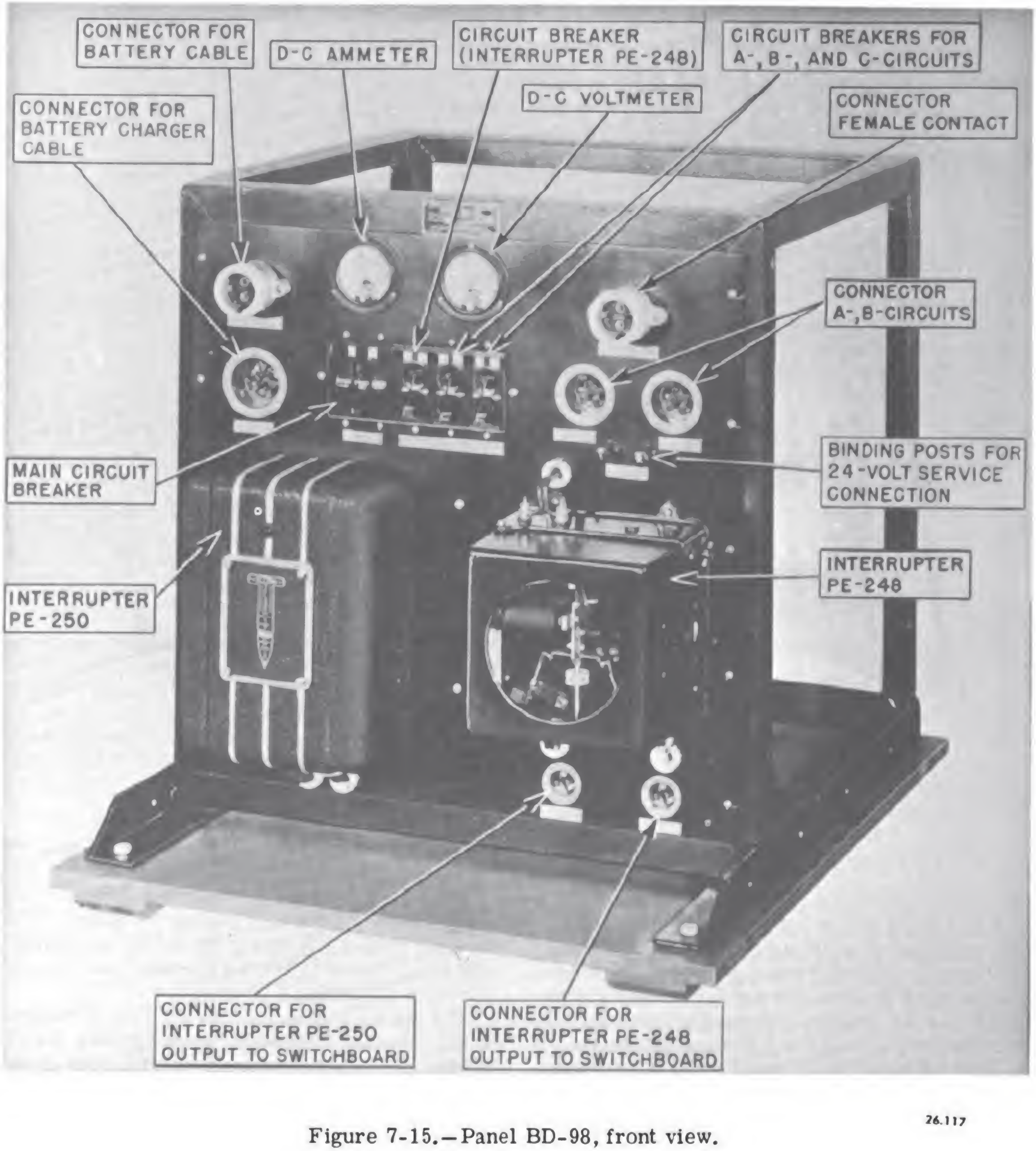
Figure 7-14.—Cabinet BE-75, front view.

The junction box (JB-19) provides a means of bringing in 24 volts direct current, 20-cycle, a-c ringing power, to the switchboard. It may also be used to extend power to a second switchboard and to group the current between the two switchboards.

The headset and chestset make up the operator's telephone set. The ground rod is used to provide the connection to ground required for protection of the switchboard equipment.

The rectifier serves to convert alternating current into direct current which is necessary to operate the switchboard. Storage batteries serve as an emergency source of power. The rectifier will most likely be of the selenium-disk type (RA-91), but the vacuum-tube type is also used (RA-36).

The panel which controls the rate of charge of the storage batteries is designated panel BD-98 (fig. 7-15). The power distribution panel also contains two interrupters which are used to supply ringing current to the switchboard. Interruptor PE-250 supplies the current when a-c power is available, and interrupter PE-248 provides ringing current when only battery power is available.



26.117

Figure 7-15.—Panel BD-98, front view.

INSTALLATION

One of the problems of installing a telephone central office set is to determine the most satisfactory location. It should be centrally located so the length of the telephone lines can be kept to a minimum. The main distribution frame should be located near an outside wall to facilitate bringing the telephone lines into the building for termination. The switchboard should be placed in a location that will give the operator maximum signal visibility. It should usually be located with the face at right angles to the window to prevent direct light from hitting the eyes of the operator. A space of at least 30 inches must be provided between the back of the switchboard and any wall or obstruction; this permits easy access to the rear for maintenance and repair. A clearance of at least 2 feet should be maintained at a side of the switchboard that is adjacent to an area that is to be used as a passageway. A minimum of 40 inches should be allowed between the keyshelf and the nearest wall or obstruction; about 6 feet is considered ideal. The batteries must be located as far from the switchboard as possible, due to explosive and corrosive fumes given off by the batteries. Place the batteries near a window for ventilation.

After your crew sets the switchboard in the desired location, see that proper installation procedures are followed.

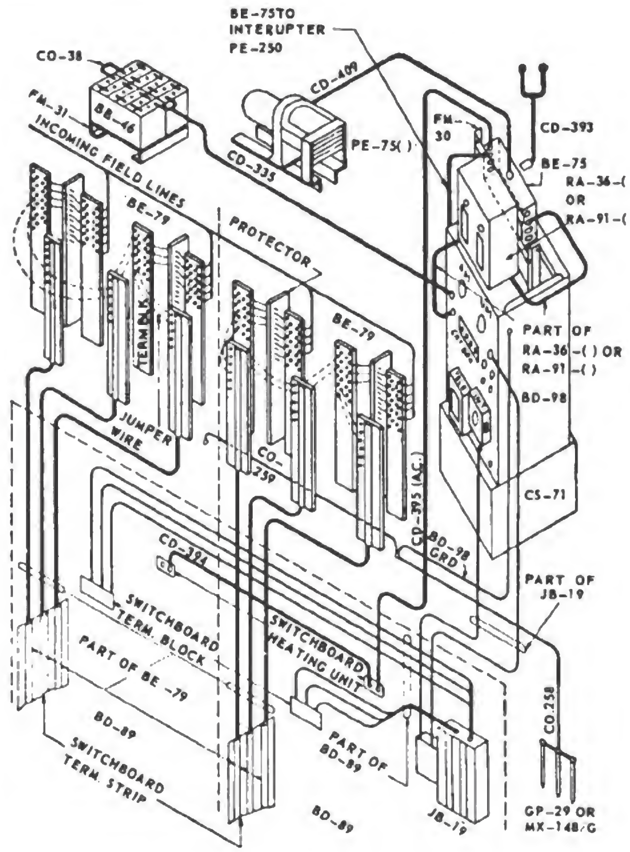
After setting the MDF in the proper location, remove the two covers, and remove the silica gel from the cabinet. Disconnect the switchboard end of cord CD-298 from the cabinet.

Set the two storage batteries on rack FM-31 and place the rack within cable distance of control panel BD-98. Place the power unit within cable distance of panel BD-98, and have the components properly connected.

If possible, the ground source should be a water pipe or similar buried metallic object of good conductivity, having a large area of earth contact. If such a ground source is not available, drive three ground rods deeply into moist earth at least 10 feet apart. Use the procedure for grounding as mentioned in setting up the BD-97 earlier.

MAKING THE CONNECTIONS

The connections between components of the set are shown in figure 7-16. If 110-volt, 60-cycle, a-c power is available, connect cord



26.118

Figure 7-16.—Telephone central office set TC-2, cording diagram.

CD-393 to the source and to the connector on the top panel of cabinet BE-75.

Be sure that the junction box JB-19 is properly mounted in the switchboard and fasten the switchboard spade terminal cable connector to the junction box.

PREVENTIVE MAINTENANCE

A preventive maintenance program may be divided into four basic operations: (1) inspecting, (2) tightening, (3) cleaning, and (4) adjusting. Inspection is the most important of these operations. Minor defects, which do not interfere with the performance of equipment, but which may lend to a major breakdown, can usually be located during a careful inspection. Have one or

more of your crew check for the following conditions:

1. Overheating as indicated by discoloration, blistering, or bulging of the parts or surface of the container; leakage of insulation compounds; or oxidation of metal contact surfaces.

2. Placement, by observing that all leads and cable are in their original positions.

3. Cleanliness, by examining all recesses in the units for accumulation of dust. Parts, connections, and joints should be free of dust, corrosion, and other foreign matter. In tropical and high humidity locations, look for fungus growth and mildew.

4. Tightness, by testing any connections or mountings that appear to be loose.

Daily Inspection

Assign someone to make a daily inspection of the switchboard exterior, night alarm bell, headset, chestset, exterior of MDF, storage batteries, and control panel BD-98. Wipe off any dirt or dust with a soft, dry cloth; never use soap and water. Clean the surface of the switchboard key shelf with a soft bristle brush. Pull the switchboard cords up as far as possible and let them hang down over the key shelf. Dust along the cord rail, being careful to prevent foreign objects from getting into the cord sockets.

The night alarm bell should be inspected whenever a new operator comes on duty. Have it tested by operating the NA key to the ON position and allowing one of the drop shutters to fall to the operated position. The night alarm bell will sound if the system is working properly.

Examine the exterior of the headset and chestset for dirt, dust, rust, and corrosion. In addition, check for chipped paint or fungus growth on the chestset. In wiping off the chestset, be careful to keep dirt or lint from getting through the holes into the face of the transmitter.

In examining the MDF, check for damaged places, chipped paint, dirt, dust, rust, corrosion, and loose, or missing screws. When tightening the screws, be careful not to force them.

Make the same checks on control panel BD-98 as on the MDF; in addition, inspect the cable connections to the panel, and examine interrupter PE-248 and the meters for cracked or broken glass. Remove dirt, dust, and lint from the wiring on the rear of the panel with a soft bristle brush.

When inspecting the batteries, check the specific gravity and level of the electrolyte in addition to the check for cleanliness and tightness of connections. Remove corrosion from the battery terminals with fine sandpaper or crocus cloth.

Weekly Inspection

Weekly inspections should be performed on the drop shutters, switchboard cords, keys, fuses, protector blocks, heat coils, repeating coils, and ground rods. Examine the drop shutters for bent or damaged latches or bent hinge pins. If necessary, adjust the shutter latches with the long-nose pliers to prevent the shutters from falling to their operating position when the switchboard is jarred. Bend the latch so that the shutter will fall freely when a call is received, but will not drop to the operating position when jarred.

The switchboard cords should be examined for dirt, dust, mildew, and fungus. Check the cord weights and pulleys for smooth operation.

Inspect the keys for tightness of mounting and loose, cracked, or broken handles. In tightening the two screws that hold the keys in place, be certain to use the proper size screwdriver. A screwdriver that is too large damages the screw slots and the bakelite cover. Tighten the key handles with the fingers, being careful not to exert pressure so great as to cause the handles to crack.

Check the fuses for correct capacity and tightness of mounting; tighten mounting screws securely, but be careful not to damage the fuse by using too much force.

Examine the protector blocks for cracked or broken porcelain and carbon blocks, dirt, dust, and foreign matter. Replace any blocks that are chipped or broken. Clean the blocks with a soft bristle brush; remove any foreign object which may be lodged between the protector blocks. Use extreme care when brushing or you may dislodge a block, thus causing trouble on an incoming line.

Inspect all heat coils for cleanliness and for chipped or broken shells. Clean with a soft bristle brush. Replace any that are defective.

The repeating coils should be checked for cleanliness and corrosion. Do not remove the metal covers of the coils. Examine the coil mountings for loose, damaged, or missing screws. Clean the coils with a clean, dry cloth.

Inspect the ground rods for rust and corrosion. See that the wing bolt at the terminal connection is tight.

Monthly Inspection

Plugs, relays, capacitors, terminals, binding posts, and cables, should be checked on a monthly inspection. The switchboard plugs should be cleaned with cord plug polish, using a clean dry cloth. All residue from the polish should be removed after cleaning in order to maintain good electrical contact.

The terminals and binding posts on the switchboard and control panel should be inspected for cleanliness and tightness. The incoming line connections should be checked for good electrical contact. Tighten any loose terminals with a proper size screwdriver or wrench. The terminals and binding posts should be cleaned with a soft bristle brush.

The connecting cables should be examined for worn or damaged insulation. The fittings on the ends of the cables should be checked for tightness and good electrical connection. The connections on the cables should be tightened as required.

TROUBLESHOOTING AND REPAIRS

When trouble in a telephone system arises, the first step in effecting repair is to assign appropriate members of your crew to determine the probable cause of the trouble. Schematic diagrams are useful in localizing the fault to a particular component. Have the crew make a complete visual inspection of the wiring and connections to the associated equipment. If no wires or connections are broken, the trouble must be located by having continuity, voltage, and resistance measurements checked. The circuit can be followed by using a systematic process of elimination. With this method the fault can normally be located within a short time. You should instruct the individual working on the circuit to start at a point where the analysis has shown the circuit to be good and proceed step by step, eliminating parts of the circuit, until the fault is located.

If visual inspection fails to reveal the source of trouble, electrical testing equipment should be used. The schematic and wiring diagrams must be carefully studied, and tests made until the trouble is located.

The use of a troubleshooting chart will simplify fault location. Charts are designed for locating troubles in various models of switchboards and equipment. Various troubles are listed, together with the probable location and the recommended correction. By using these charts, troubles can frequently be isolated to one part of the equipment, thus saving time-consuming checks on trouble-free components.

Many repairs can be effected by simply replacing a fuse, lamp, cord plug, strap, or similar item. Other repairs require nothing more than cleaning a contact, cord plug, or grouping key. Adjusting a screw, a spring, or line drop will often make equipment operable.

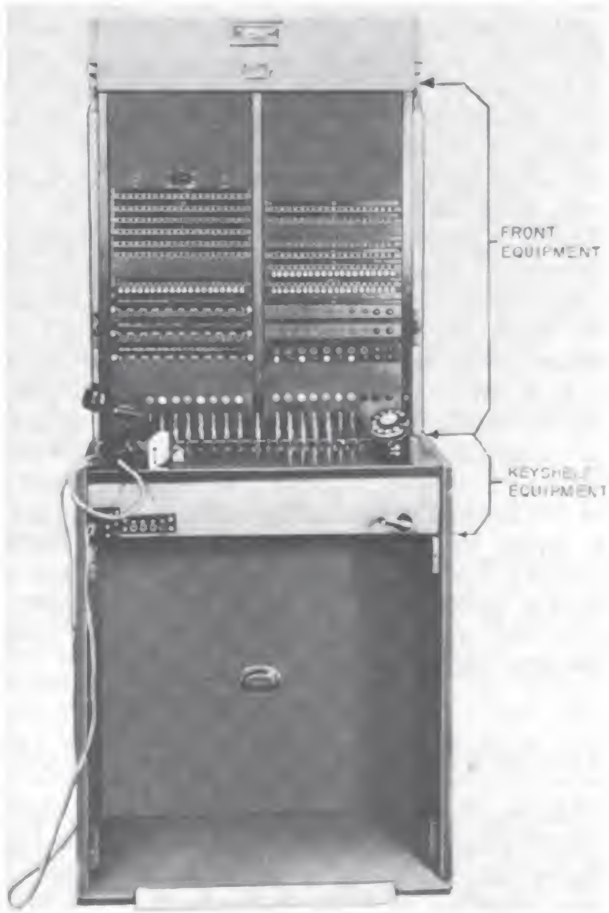
Some repairs, of course, are rather complex, as for example repairs to switchboard cords and repairs to combined jacks and signals. Space does not permit a discussion of all such repairs. The <u>Army Technical Manual</u>, TM11-340, which describes the TC-2 telephone set, contains a complete discussion on all phases of maintenance and repair for the switchboard and associated parts.

TELEPHONE CENTRAL OFFICE SET TC-10

Telephone set TC-10 is a complete transportable telephone central office for use at any advance base requiring a telephone switchboard of the capacity of 1 to 6 switchboards BD-110. The number of switchboards to be used in an installation is determined by the number of lines to be served and by the expected maximum calling rate. For each switchboard BD-110 used, a maximum of 60 common-battery lines, 30 local-battery (magneto) lines, and 4 two-way trunks may be connected, and a maximum of 15 conversations can be handled at one time. The magneto line circuits can be used for magneto lines, toll lines, or inter-office, two-way ringdown trunks. The trunk circuits may be used for trunks to manual or automatic (dial) exchanges. The anticipated normal installation is three switchboards BD-110, and this number will normally be furnished with telephone central office set TC-110.

SWITCHBOARD BD-110

The switchboard BD-110 (fig. 7-17) is a single-position, two-panel, manually operated telephone switchboard. The lower section of the



26.119
Figure 7-17.—Switchboard BD-110, front view.

switchboard contains the cords and a rack upon which are mounted the cord circuit relays, operator's telephone circuit apparatus, universal trunk circuit apparatus, and switchboard fuses. The upper section of the switchboard is occupied by the jack and signal equipment, the cabling therefrom, and the terminal panel. The terminal panel is formed by one section which, supported by top bolts, can be swung out for access to the jack and signal equipment and wiring. The terminal panel provides 800 binding posts in 16 vertical rows of 50 binding posts per row. Lamp signals are provided for signaling on magneto lines. Multiple jacks are provided for use when two or more switchboards are used. The answering and multiple jacks are wired to flexible cables which are equipped with spade terminal strips. These strips are arranged for connection to the binding posts on the terminal panel of the same or another switchboard. This arrangement permits making rapid multiple jack connections between switchboards. A smaller spade terminal strip with four flexible cables permits connections to battery, ringing, alarm, and grouping circuits. The cord circuits are fully universal, and can be used to interconnect all lines and trunks.

Each switchboard BD-110 contains the following circuits:

1	Operator's telephone circuit
1	Auxiliary operator's telephone circuit
1	Dial-cord circuit
30	Local-battery (magneto) line circuits
60	Common-battery line circuits
4	Universal trunk circuits
15	Cord circuits (fully universal)
1	Power and heating circuit
1	Conference circuit (10 jacks)
1	Grouping key circuit
1	Emergency-ringing circuit
1	Keyshelf and framework ground circuit

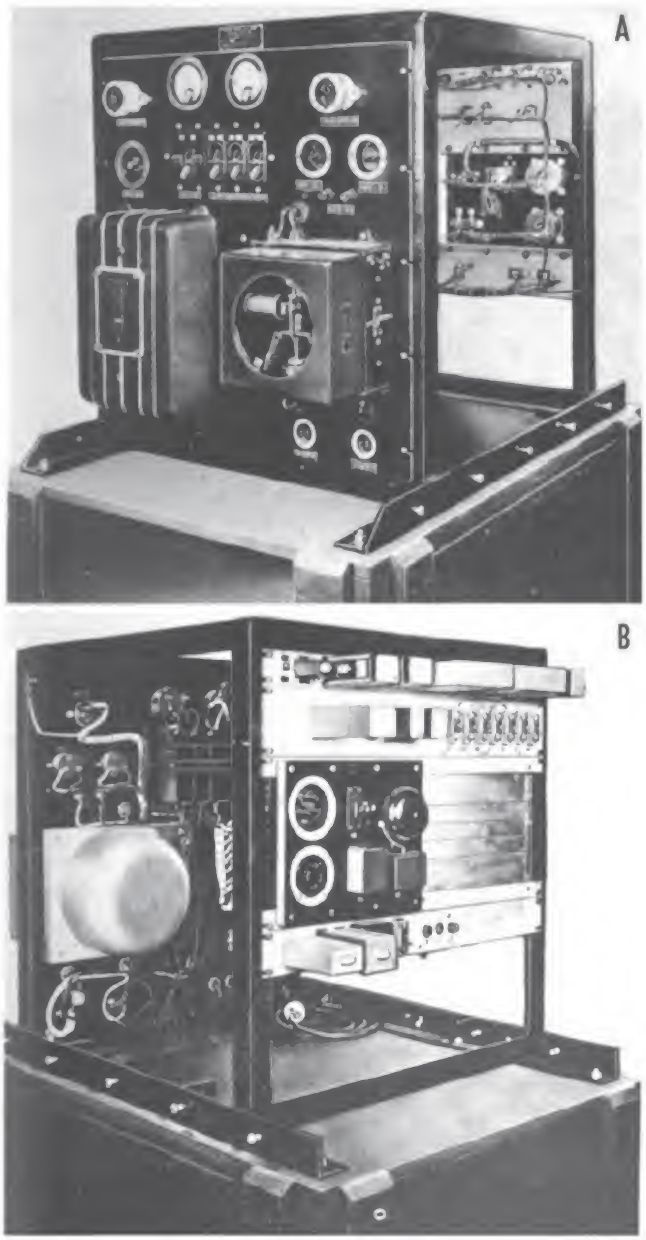
POWER EQUIPMENT

Batteries

Four storage batteries BB-46, connected in series by cords CO-38, provide the 48-volt battery required for relay operation, talking battery, and so on. Battery BB-46 is a 12-volt, 75 ampere-hour sealed type battery. One 45-volt dry-cell battery BA-26 is required for the voltmeter test circuit of cabinet BE-72, and twenty 1.5-volt dry-cell batteries BA-23, connected in series, are required to furnish 30 volts for the test cabinet BE-70.

Rectifier RA-36

The rectifier is used to charge the 48-volt storage battery. It is a full-wave rectifier designed to mount on a rack and to operate from a 105 to 125-volt, 60-cycle, a-c power source. When used to charge a 48-volt (24-cell) battery, it can be adjusted to charge at a rate of 2 to 12 amperes. To ensure that the charging current does not cause noise in the telephone circuits, an external filter reactance, mounted on the rear of the rack, is connected in the positive charging lead.



A. Front view.
B. Rear view.

26.120

Figure 7-18.—Panel BD-90.

PANEL BD-90

Panel BD-90 (fig. 7-18) serves as a control and connecting point for the 48-volt battery circuits, as a source of ringing power for the switchboard, and as an alarm panel. The front panel is equipped with receptacles and binding posts for connection to the battery and rectifier, and to the switchboard or other equipment requiring 48-volts direct current. Circuit breaker switches on the panel control the power supply to the switchboard or other equipment, and in addition protect these circuits against overload. The lower part of the front panel is equipped with a telering (vibrator-type) power ringer to obtain 90-volt, 20-cycle ringing power from a 110-volt, 60-cycle supply. It is also equipped with a vibrating interrupter which has a ringing transformer to obtain ringing power from the 48-volt storage battery. Equipment is mounted on the rear panel for the following circuits:

1 Contact protection circuit for the ringing interrupter
1 Night alarm circuit (including the battery supply fuses for the line lamps on the switchboard)
1 NO-voltage alarm circuit (ringing voltage alarm)
1 Fuse alarm circuit
1 Voltage supply circuit for cabinet BE-72 voltmeter test circuit

POWER SUPPLY

The telephone central office set TC-10 is designed to operate on a commercial source of 110-to 120-volt, 60-cycle alternating current. A 50-foot cord CD-393 is provided to connect a 110-volt outlet to the a-c distribution cabinet BE-75. When commercial power is not available, two power units PE-75, included with the set, can be used to furnish the power. Each of these units consists of a gasoline-engine coupled to an a-c generator. This generator will deliver 2500 watts at 120 volts and 60 cycles. A 50-foot cord CD-409 is provided to connect power unit PE-75 to the a-c distribution cabinet BE-75.

TEST AND POWER DISTRIBUTION EQUIPMENT

Cabinet BE-72

In use, cabinet BE-72 (fig. 7-19) is mounted on top of a centrally located switchboard. In this position, it serves as a distribution point for the power and alarm leads and as a test

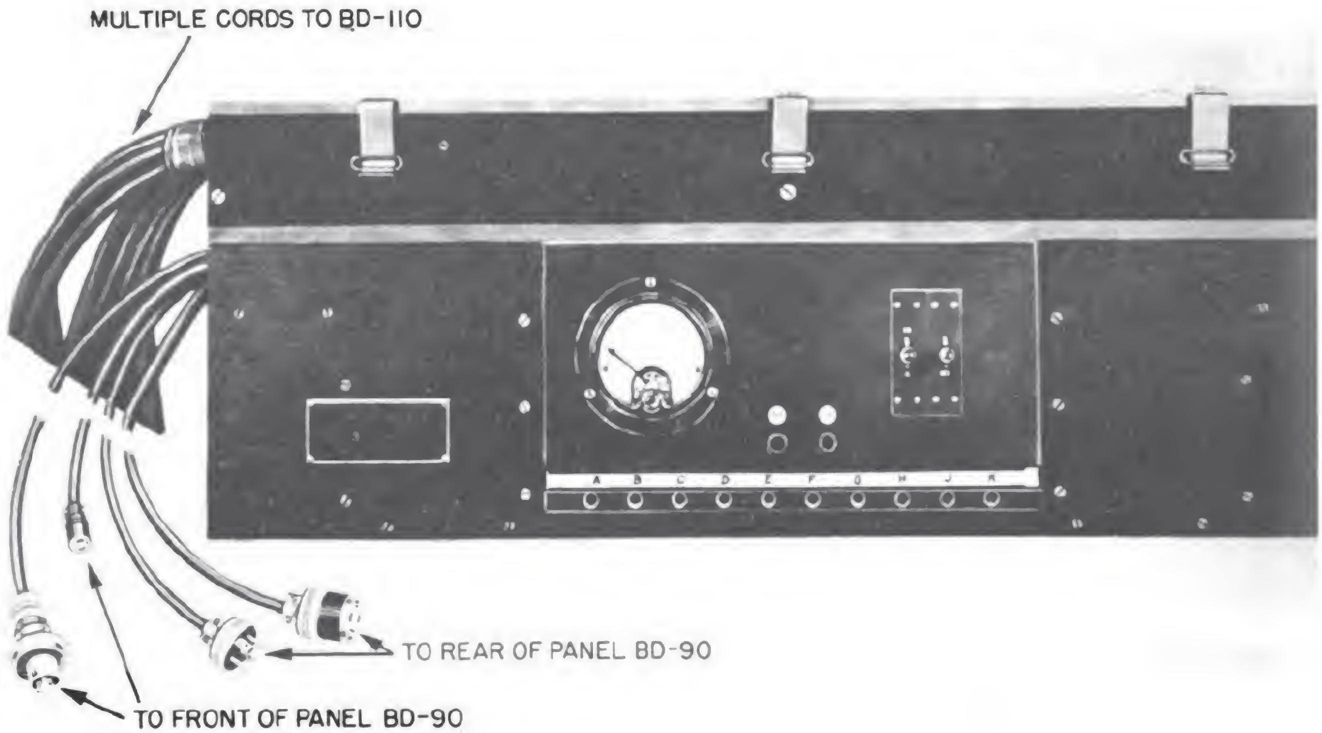


Figure 7-19.—Cabinet BE-72, front view.

panel for the cord circuits and line circuits of switchboard BD-110. The switchboard circuits may be given routine tests by using jacks A to J. The equipment located above these jacks is associated with the voltmeter test circuit. The lines and trunks connected to switchboard BD-110 may be tested by using this circuit. An additional feature permits ringing the bells on a line having a receiver off the hook if the bells are connected between either side of the line and ground.

Cabinet BE-70

The wire chief's test cabinet BE-70 contains a 100,000-ohm, d-c voltmeter having a range of 0-40 volts with keys and connections which enable the testman to test for and locate practically all line faults. Provision is made for connecting a Wheatstone bridge to the line under test, for talking and ringing on the line under test, and for talking on call wires or trunks to operators, testmen, and so on. In use, the cabinet is placed on top of packing case CS-70, for ease of operation. (For additional information on the BE-70, refer to TM 11-345.)

LOCATION

Telephone central office set TC-10 should be installed in a protective enclosure. In humid climate, choose as dry a location as possible. In dry desert country, or in cold climates where the ground is frozen to a considerable depth, choose a location near a good source of ground if possible. The equipment may be located as desired, with the limitations as shown in figure 7-20.

The batteries and power units PE-75 should be installed in an enclosure separate from the switchboard to keep the switchboard room reasonably quiet and free from battery fumes and exhaust fumes.

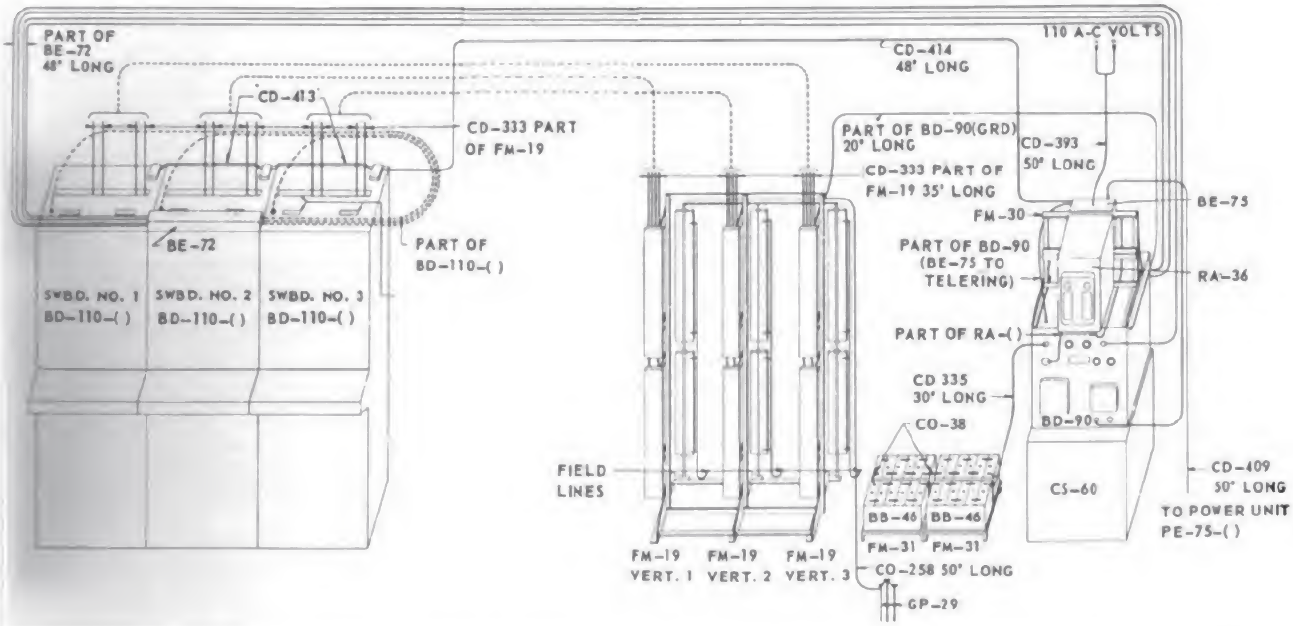


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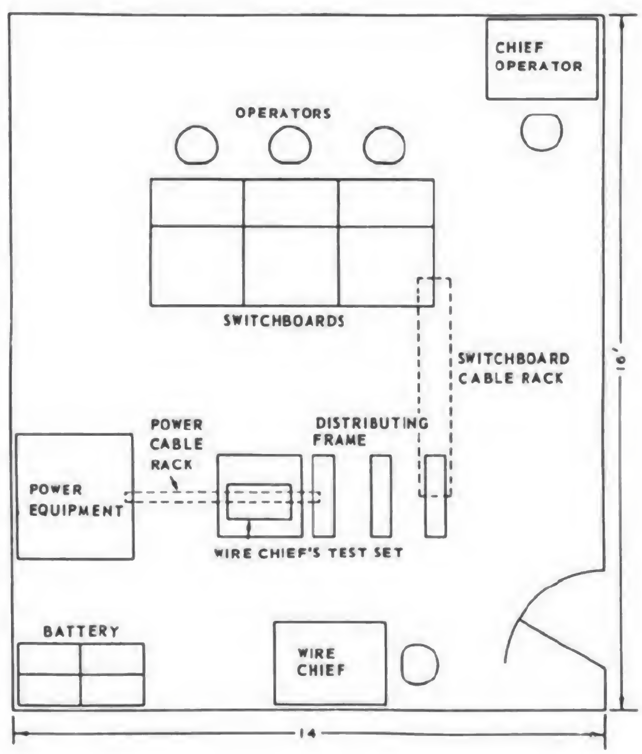
Figure 7-20.—Cording diagram of telephone central office set TC-10.

Figure 7-21 shows a suggested floor plan where space is limited. Figure 7-22 illustrates a preferred arrangement using two rooms. Where a large room is available, the set arrangement may be similar to the setup shown in figure 7-23. The room shown is approximately 25 feet long. Space between the different component and between the equipment and the walls is essential for proper maintenance.

When choosing a location for the switchboard, consider the switchboard operator. Best operator performance can be obtained in a well-ventilated room which is not brightly lighted. Bright lights on the face of the switchboard makes the signal lights hard to see. Keep noise down so that the operator can easily hear.

SETTING UP EQUIPMENT

Have your crew set the required number of switchboards in place and instruct them to erect the main distributing frame. Using as many frames FM-19 as the number of switchboards BD-110 installed. Then properly set in place the frame which will be nearest the switchboard. Have the small parts and adjacent frames FM-19 assembled in the order shown by the numbers in figure 7-24.



26.123

Figure 7-21.—Suggested floor plan for telephone central office set TC-10 in one room.

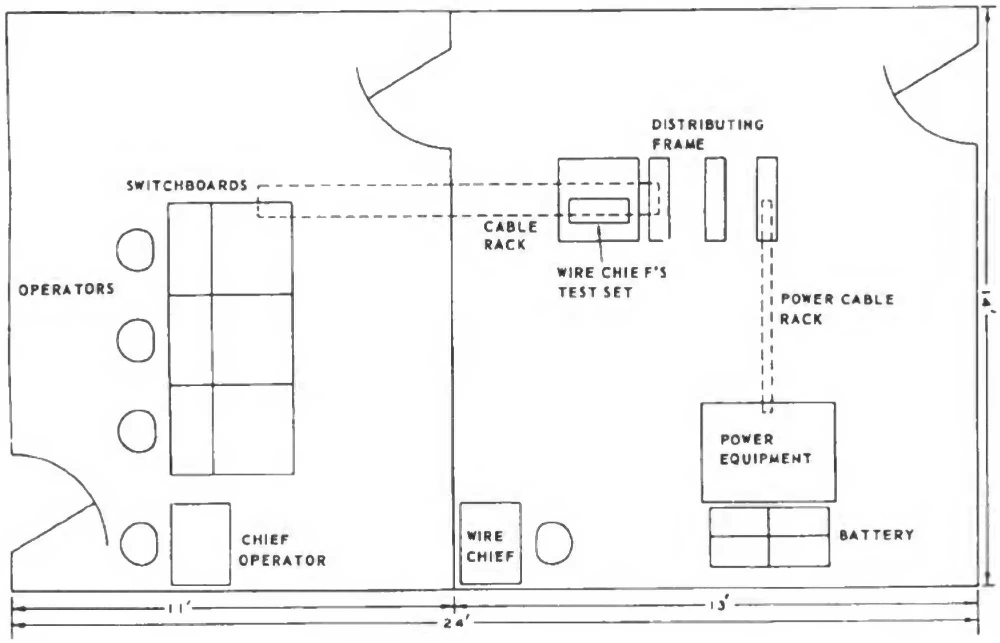


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Figure 7-22.—Suggested floor plan for telephone central office set TC-10 in two rooms.

If possible, locate a good ground source such as a water pipe or other buried metallic object of good conductivity having a large area of earth contact. If this is not possible place ground rods as mentioned previously in setting up telephone central sets TC-2 and TC-4.

CONNECTING EQUIPMENT

All connections between units of equipment, except the connections to cabinet BE-70, are shown in figure 7-20. Before any of your men make any connections be sure that they place the switches on panel BD-90 rectifier RA-36, and cabinet BE-75 in the OFF position.

One of the final operations will be to connect the four storage batteries BB-46 in series, using cords CO-38, to form a 48-volt group. Connect the battery to the BAT CABLE outlet of panel BD-90 using cord CD-335.

CAUTION: Poor connections at the battery, liable to arcing, are a fire hazard.

When an outside source of power is not available, connect cord CD-409 from power unit PE-75 to cabinet BE-75.

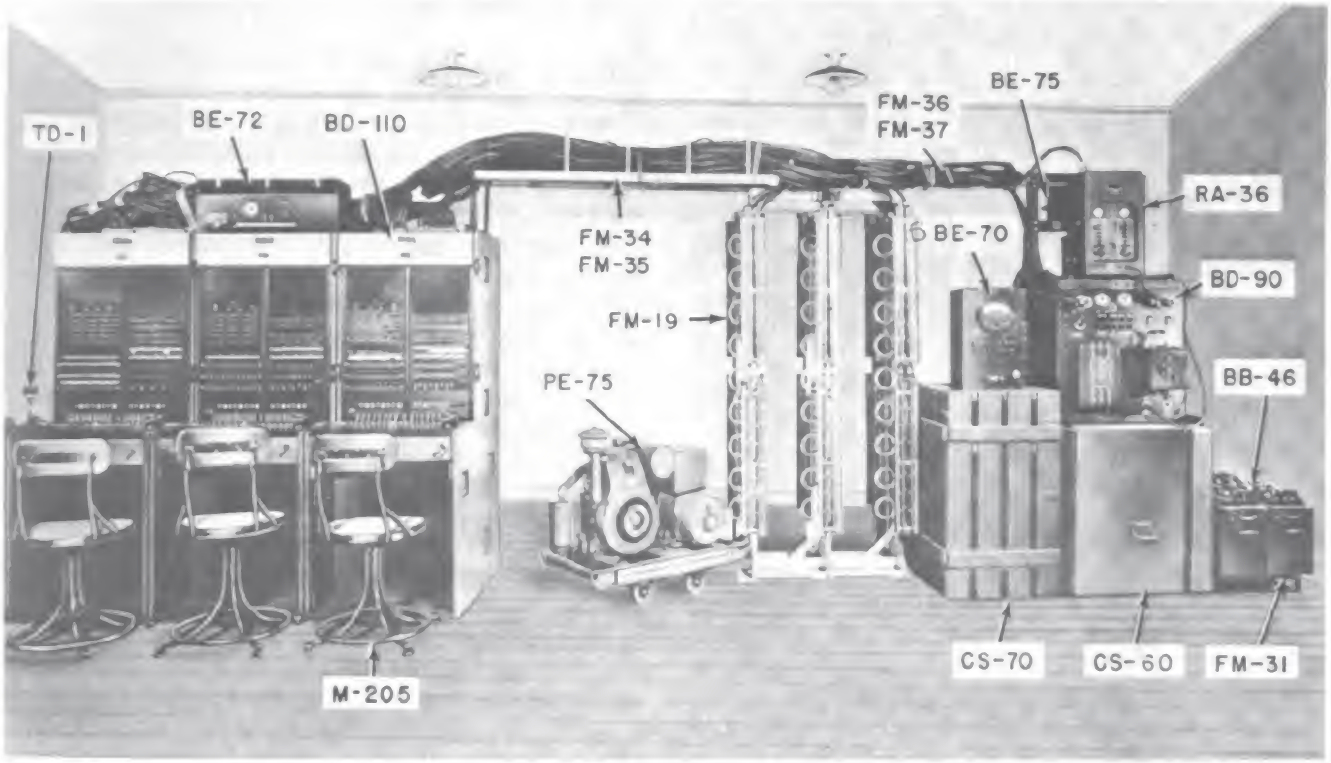
PREOPERATIONAL CHECK

After your crew has set up the telephone central office set TC-10, you should have them make the following preoperational check:

1. Place the MAIN circuit breaker switch of panel BD-90 to the ON position. The voltmeter must read approximately 50 volts. A reading much different than this indicates wrong battery connections and must be corrected before proceeding.

2. Operate the switch of cabinet BE-75 to connect the power to rectifier RA-36. Set the rectifier coarse adjustment plugs to holes No. 8. Make sure that neither fine adjustment (lower) plug is inserted. Then operate the switch on the rectifier to the ON position. If both bulbs light, insert the fine adjustment plugs into the holes marked LOW. The ammeter on panel BD-90 should show a small current in the charge direction.

3. Operate the G key on the rear of panel BD-90 to the TEL position. The no-voltage alarm buzzer will sound. Operate the switch of cabinet BE-75 which controls the telering ringer. The alarm buzzer should stop, indicating proper operation of the telering.



26.125

Figure 7-23.—Telephone central office set TC-10, assembled.

4. Check the fuse alarm circuit by temporarily connecting the alarm stud of a fuse block to the battery. The fuse alarm buzzer should sound. Test fuse blocks on the rear of panel BD-90 and of switchboard BD-110.

5. When possible, test the cord, line, and trunk circuits.

MAINTENANCE

Maintenance procedure for the TC-10 will be similar to that of the TC-2. However, as the supervisor, you should make up a routine maintenance check sheet and see that it is followed.

OUTSIDE TELEPHONE PLANT SYSTEMS

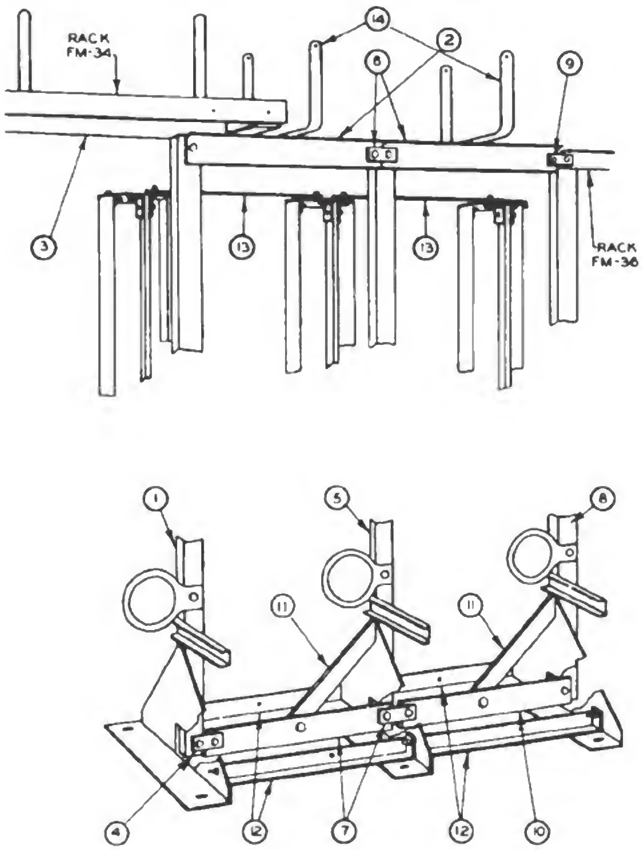
The preceding paragraphs discussed the various types of advance base telephone central office sets. Telephone sets, switchboards, and their components were explained in detail, but nothing was said about the outside plant system. Field wire (transmission) line is a major element in all telephone systems.

PLANNING

As chief or first class Construction Electrician you may be asked to help plan the installation of the field wire lines. In the planning of field wire lines, consideration should be given to the type of line required, the service qualities of the proposed line, and route to be followed. Careful planning and construction of a line will result in a reduction of maintenance, improved transmission, and a saving of time, labor, and materials.

Selecting the Type of Line

To determine the type of line to be built, the primary factors are: (1) the type of equipment available, (2) the number and quality of circuits required, (3) the length of the line, and (4) the time available for installation.



26.126
Figure 7-24.—Distributing frame, assembly diagram.

Service Qualities

To estimate the service qualities of the proposed line, consideration should be given to the relative transmission characteristics of the different types of field wire when laid on the ground, when buried, or when installed aerially on overhead supports.

Overhead lines, in general, give longer transmission ranges and provide greater physical protection for the circuit than other types of construction.

In surface-line construction, reliability is directly proportionate to the care and skill exercised in installation. Surface lines laid carefully, with consideration to ties, road crossings, and other means of protection, provide a reliable type of line suitable for certain advanced base requirements. On the other hand, wire lines laid rapidly on the ground without regard for policing require immediate and continuous maintenance, and are justifiable usually ONLY under EMERGENCY conditions.

Selection of Route

When the line is planned, the shortest and most effective route should be selected to allow construction with a minimum of time and materials. Factors that should be considered are the availability of materials, equipment, and construction personnel; traffic requirements; specific requirements for the line; and the terrain, which should include a study of the map of the area, supplemented by ground reconnaissance. Difficult terrain should be avoided to reduce the need for special construction and to reduce the loss in speed and efficiency.

Continuous liaison should be maintained with all units engaged in road building and road improvement to avoid routing lines where there is a possibility of damage to the line from road construction. If it is imperative that wire lines be laid along roads where construction work is being done, maintain coordination with construction units to guard against unnecessary interruption to wire communication. Where there is a possibility that the initial type of installation will require a change to a more permanent type or where the lines may be used again by the same unit or another unit in the event of a move, choose the route that will make the change as easy as possible. Wherever possible, avoid compact or built-up residential areas. Wire facilities are difficult to install and maintain in congested areas. Use a cross-country route whenever practicable. Before the wire lines are laid, you, as construction chief, should reconnoiter the route.

Before you get started on the construction, you should look for the following features along the route:

1. Number of overhead crossings
2. Number of underground crossings
3. Number of railroad crossings
4. Type of terrain and the type of construction best adapted to available wire-laying equipment.
5. Number of stream crossings
6. Distance in miles
7. Any obstacles to maintenance

The next step is to select and mark clearly on a map the exact route along which the wire is to be laid. If no map is available, sketch a map of the area using some identifying objects along the route.

SURFACE-LINE CONSTRUCTION

Surface-line construction has two principal advantages: (1) A minimum of time is required for installation, and (2) loosely laid wires are less vulnerable to bombing than other types of construction. The two main disadvantages are: (1) Surface lines may become unserviceable in wet weather as a result of leakage to the ground, and (2) surface lines may be easily broken by the movement of personnel and vehicles.

In setting up surface-line construction, you should instruct your crew to proceed as follows:

1. Before starting construction, test the wire for the circuits to assure the continuity of each reel. Reels of wire that do not show a continuous circuit when tested are not used until the wire has been serviced.
2. At the starting point, tag the free end of the wire with the circuit designation. Place this tag 1 foot from the end of the wire.
3. Leave enough wire at the free end to reach the switchboard terminal strip or other installation, and tie the wire into some fixed object.
4. Connect the free end of the wire to the construction center terminal strip when one has been installed, to the switchboard terminal strip or to a telephone set.
5. After each splice is completed, test back to the starting point from the far side of the splice to assure continuity of the circuit. To avoid making pinholes in the wire insulation from test clips, test the bare wires from the far side of the splice before taping is started. During the taping process, be careful not to cause circuit trouble. When connections are made at terminal strips, make a test from the far side of the connection back to the starting point. All circuits should be tested before they are reported.

Test Stations

To facilitate the testing and rearranging of circuits, test stations should be installed on a wire line. Test stations may be located at points where circuits diverge, at the end of a wire line that does not terminate in a switchboard, near points where circuits are most exposed to damage, at probable future locations of expansion, or at other convenient points on the line. When a unit is located where a test station has previously been installed, the test station can be converted easily into a telephone central.

Connections Between Surface Lines and Pole Lines

Connections between surface lines and pole lines are made conveniently at established terminals or test stations. Whenever such connections are made, tie the surface line securely and tag it at the base of the pole at which the connection is made, then tie the line again just above the crossarm or terminal where the lines connect.

AERIAL CONSTRUCTION

A line attached to trees or other supports to provide the necessary clearance from the ground surface constitutes an aerial line. Cable that is intended to be laid directly on the ground but that is casually supported by underbrush or thickets is classified as ground-surface construction. The aerial construction method and techniques will not be discussed in this manual (discussed in CE 3&2). However, you are responsible for supervising the installation of aerial lines on poles, trees, or 4 X 4 sawed lumber or equivalent.

DIAL TELEPHONE SYSTEM

It is not the intent of this manual to cover the dial telephone system in its entirety, but to discuss some of the fundamentals dealing with the central office building requirements, automatic functions, trunking equipment, the attendant's switchboard, test desk, main distributing frame, and the power, alarm, and metering equipment.

When you are assigned a project of installing a dial telephone system, you will receive a number of manufacturer's drawings showing cabling, system schematics, supervisory circuits, equipment locations, and interconnections. You should become thoroughly familiar with these plans so you can properly supervise the operation of your crew.

CENTRAL OFFICE BUILDING REQUIREMENTS

The site selected for a dial central office building should be slightly higher than its surroundings to ensure adequate drainage. Avoid low-lying sites which are likely to flood or

remain excessively damp after heavy storms. In areas with heavy prevailing rainfall and poor natural drainage, the main floor of the building must be well above ground, and must be protected by earthworks and ditches.

Space Requirement

The building should be of such size and shape that the various units of equipment can be located for most efficient operation and maintenance.

If the central office is to include an attendant's switchboard for the manual servicing of certain calls, the switchboard should be installed in a separate room. This will help to isolate the operators from the noise made by the stepping switches.

The switching equipment and the power equipment may be installed in one room. It is desirable, however, to install the switching equipment in a separate room to minimize preventive maintenance. The central office battery is often installed in a separate, ventilated room, as close to the power board as possible. Modern sealed-type wet cells may be installed in the switchroom proper. If this is done, however, the room should be air-conditioned.

Floor Loading

Generally you will not be concerned about the floor load of any new structure for housing dial telephone system equipment. If the system is to be located in an old building, the floor joists and support should be carefully inspected. If you feel that you are not qualified to make the inspection, you should check with the Chief Builder or some other competent personnel to ensure adequate safety of the floor. If repairs are necessary, they should be completed before moving the equipment into the building.

External Power Source

AN ADEQUATE SOURCE OF 3-PHASE, 220-VOLT, 60-CYCLE POWER MUST BE AVAILABLE for dial systems. If power source is not available, be sure that it is provided, before any communication equipment is installed. Also see that adequate lighting is provided.

AUTOMATIC FUNCTION

The central office equipment required to establish automatically a connection between two telephones is known as a link. The simplest link exists in an exchange servicing less than 100 telephones. This link is made up of two elements, a linefinder and a connector. In an exchange serving more than 100 lines and less than 1000 lines, a link consists of a linefinder, a selector, and a connector. In an exchange of more than 1000 lines and less than 10,000 lines, a link consists of a linefinder, a first selector, a second selector, and a connector.

The equipment required to establish automatically a connection between two telephones served by a 100-line system consists of telephone lines connecting the telephones with the exchange, line equipment relays, a linefinder, and a connector.

Each telephone has its own individual line, consisting of two metallic wires that connect it to the central office. These wires may be strung with others on crossarms of poles, or they may be a pair of wires in an aerial cable or an underground cable. The telephone lines are connected to the inside equipment through the main distributing frame.

Each line served by the exchange is connected to line-equipment relays. When the handset of a calling telephone is picked up, the line-equipment relays actuate linefinder guard-circuit relays to seize an available linefinder. Another function of the line-equipment relays is to busy out the line (make the line unavailable for other calls) while the telephone is being used.

All the linefinders that serve a group of telephones are controlled by a guard circuit. The relays of the guard circuit, actuated by the line-equipment relays, function to seize an available linefinder. Tens and units relays in the linefinder, corresponding to the tens and units digits of the calling telephone, operate to extend the call to an available connector. The guard circuit prevents seizure of a linefinder by more than one telephone line if two or more handsets are picked up simultaneously. After causing a linefinder to be seized, the guard-circuit relays drop out of the circuit to become available for another call.

When a line is extended to a linefinder, the connector control relays are actuated to seize an available connector. Dialing the first digit of the called telephone causes the proper connector tens relay to operate. Dialing the second

digit causes the desired connector units relay to operate, thus completing the connection between the calling telephone and the called telephone.

Links are wired in parallel (multiple) to the telephone lines. This arrangement makes it possible for any one of the links to complete a connection from any calling telephone to any called telephone in the group. The number of links wired in parallel for the group is based on the expected calling rate or the number of simultaneous calls, because one link is engaged for each talking connection. The lines from all telephones in the group are connected to both the linefinder and connector of a link.

Figure 7-25 shows how the talking connection is established through the linefinder and connector of a link. One wire is used to represent each line, and only 30 lines (three groups of 10) are shown to illustrate the principles involved. The wires for each group of 10 lines are connected to contacts of the linefinder tens relays and to the contacts of the connector tens relays. In both the linefinder and the connector, there are 10 relays to accommodate 100 lines. These relays are numbered to correspond with the tens group of lines connected to the relays: F-10, F20, and so on through F-00 in the linefinder; C-10, C-20, and so on through C-00 in the connector. The contacts of the linefinder tens relays, with identical units digits, are wired in parallel and are connected with the contacts of the correspondingly numbered units relays. For example, the contacts of tens relays F-15, F-25, and F-35 are wired in parallel and connected with the contacts of relay F-5; the contacts of ten relays F-41, F-61, and F-81 are wired in parallel and connected in parallel with

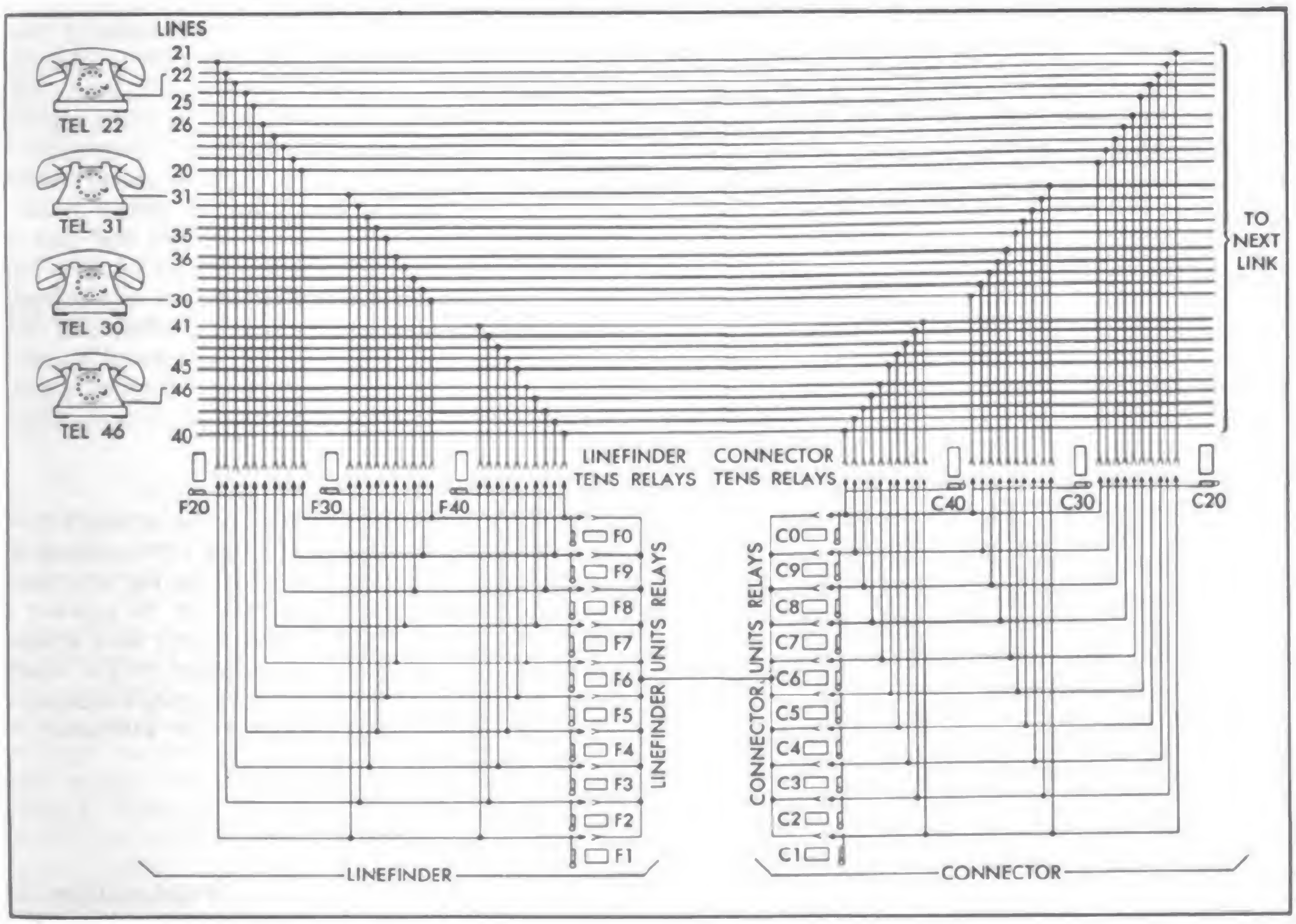


Figure 7-25.—Simplified schematic diagram of link.

the contacts of relay F-1. Similarly, in the connector, the tens relay contacts that have identical units numbers are wired together, in parallel, to the contacts of individual connector units relays numbered C-1, C-2 and so on through C-0.

When the handset of the calling telephone is lifted, the linefinder tens relay corresponding to the tens digit of the calling telephone operates, connecting all 10 lines of the group to their corresponding linefinder units relays. The units relay corresponding to the units number of the calling line then operates automatically and extends the calling line to the connector. The number of the called telephone must now be dialed to complete the connection. Dialing the tens digit causes a connector tens relay to operate, connecting its associated 10 lines to the connector units relays. Dialing the unit digit causes the operation of one of the units relays, and the talking connection is completed. For example, in a call from telephone 22 to telephone 34 (fig. 7-25), linefinder relays F-20 and F-2 operate automatically when the handset is lifted, to connect the calling telephone to the connector control relays. Dialing 34, the number of the called telephone, causes connector relays C-30 and C-4 to operate and complete the talking connection.

TRUNKING EQUIPMENT

Provisions are made in dial exchanges to permit the telephones served by the exchange to be connected with other exchanges. If the other exchange is automatic, the circuits that provide connections between the exchanges are called auto-to-auto trunks. If it is manually operated, the circuits that provide connections between the exchanges are called central office (city) trunks; the designation "city" is found on the exchange equipment, and usually indicates auto-to-manual trunks. Calls from attendant's switchboard (cabinet) to telephone users are made over circuits called out-dial (or local-dial) trunks.

Nondial telephones operating over common battery lines or over magneto lines may be served by a dial exchange. In such cases, the common battery and the magneto lines are connected with the attendant's switchboard of the dial exchange. Such arrangements permit the attendant to establish connections manually between the dial telephones of the exchange and the nondial telephones connected with it.

In most dial exchanges, dialing the digit 0 connects the telephone with the attendant's switchboard. Similarly, dialing digit 9 connects the telephone with a distant manually operated exchange, and dialing digit 8 connects the calling telephone with a distant automatic exchange.

The term "attendant's switchboard" is the official terminology for the equipment often described by telephone personnel and in manufacturer's specifications and drawings as the attendant's cabinet. Such a switchboard may consist of one or several complete switchboard sections or positions, depending on the size of the exchange, the expected calling rate, and the types of service to be provided by the central office concerned.

ATTENDANT'S SWITCHBOARD (CABINET)

The attendant's switchboard provides facilities for an attendant to establish talking connections manually when they can not be dialed, and also to furnish information. Calls to and from magneto and common battery lines can be handled at the attendant's cabinet. Information and out-dial trunks permit calls to and from the attendant, respectively. Central office trunks terminate at the attendant's cabinet and can be connected to any telephone served by the exchange. The attendant's switchboard is equipped with several cord circuits to establish the desired connections, and the attendant's telephone can be connected to these cord circuits.

Cord Circuit

A cord circuit is used by the attendant to interconnect circuits or trunks terminating at the attendant's cabinet. In addition, the attendant uses a cord circuit to initiate or to answer a call. The cord circuit is associated with equipment that also permits the attendant to dial. When a call has been terminated, the signal associated with the cord circuit notifies the attendant to disconnect the circuits.

Telephone Circuit

The attendant's telephone circuit enables the attendant to talk on any circuit terminating at the attendant's cabinet. The circuit further provides talking battery and arrangements for connecting the attendant's headset to any cord circuit.

TEST DESK

The test desk is used to test outside plant facilities (line and telephones) served by the exchange. To test the quality and condition of the outside lines, measurements are made of line resistance, and of line leak resistance between conductors and between conductors and ground. Other tests are made for foreign battery on the lines, proper connection of telephones, correct dial speed, and proper ringing of called telephones. Tests may be made from the test desk through a test connector, a test shoe, or test clips.

A test connector may be used to connect a particular line to the test desk. The test connector is first engaged and then, by dialing the last two digits of the desired telephone, a line is connected to the test desk so that tests can be made.

The line to be tested may be connected to the test desk by a cord that terminates in a test shoe or in test clips. These clips are attached to the line at the main distributing frame.

When a headset is not replaced on the hookswitch of a telephone, a howler tone may be connected to the line at the test desk. The receiver then emits a howl to call attention to the need of replacing the handset. A switch in the test desk is used to connect the howler equipment to any desired line through a test connector.

MAIN DISTRIBUTING FRAME

The main distributing frame serves two functions, (1) to connect the inside equipment with the outside lines, and (2) to interconnect various units of the inside equipment.

The outside-line wires normally are terminated on protector terminals on what usually is referred to as the vertical side of the MDF. The protectors protect the inside equipment to which the line is connected from high-voltage damage caused by lightning and from damage that might be caused by lower, but harmful, foreign voltages. Such voltages may be introduced by contact between telephone lines and power lines.

The cables from the inside-line equipment normally are terminated on what usually is referred to as the horizontal side of the MDF.

The line wires on the vertical side of the frame are connected to the inside-line equipment on the horizontal side of the frame by cross-connection wires (jumpers). These jumpers connect the line terminals to the terminals of the inside equipment required for a particular line or service.

The terminal blocks on the horizontal side of the MDF may be used to make semipermanent connections between units in the exchange.

POWER, ALARM, AND METERING EQUIPMENT

The power equipment is made of all the components necessary for the generation, storage, and control of energy for an automatic exchange. This equipment includes the motor-generator sets, the battery, the power panel, the alarm equipment, and the metering equipment.

Motor Generators

The dial exchange is equipped with two motor-generator sets. Each motor operates from a 220-volt, 60-cycle, 3-phase supply, and each generator will supply a maximum of 25 amperes at a constant potential of 51.6 volts. Under normal or light load operating conditions, one motor-generator set will supply the d-c needed by the exchange, and enough to keep the exchange battery charged. Under heavy exchange load conditions, or when a battery is almost completely discharged, both motor-generator sets may be operated simultaneously.

Battery

The dial exchange is usually equipped with a 24-cell lead-acid type storage battery, which will furnish d-c for the exchange when the motor-generator sets are not in operation. The battery and the motor-generator sets are connected in parallel, so that any one of the three sources can supply the energy required to operate the exchange.

Power Panel

The power panel contains the control elements, fuses, and power meters related to the distribution of power to the units in the exchange.

Alarm Equipment

The alarm equipment provides a means of notifying the operating personnel of trouble in the system. The alarm lamps and buzzers mounted on the power panel operate when a fuse in any of the units of the exchange is blown. Each alarm lamp is labeled with the name of the unit it serves.

Metering Equipment

Several counter-type meters, labeled CALL and OVERLOAD, are mounted on or near the power panel. The call meters register the number of calls handled by various units of the exchange. The overload meter registers the number of times the various units in the exchange become overloaded (capacity exceeded by the traffic demand).

INTEROFFICE COMMUNICATIONS SYSTEMS

An interoffice communicating system is used to transmit orders and information among officers that are only a short distance apart. Frequently such offices are in the same building. Intercoms are not used at all advanced bases; if they are used, and there is no I.C. Electrician attached to the base, the job of installing, maintaining, and repairing them usually falls to the CE.

Assembling an intercom set requires considerable knowledge of the principles of electronics. For this reason, intercom sets intended for use at advanced bases are packed ready for operation. By observing a few simple rules and following the wiring diagram (fig. 7-26) that accompanies the set, you should be able to make the installation without difficulty.

An intercommunicating system consists of one or more master stations, a junction box, one or more remote speaker units, and the wire necessary to make the connections. One type of intercom set used by the Seabees is shown in figure 7-27. The master station (chassis shown in fig. 7-28) has a capacity of 12 remote speaker-microphone units; however, if one or more of the remote units are master stations or if one or more of the remote units are connected to the call-in circuit, the capacity of the system is only 11 remote stations.

The basic parts of the master station consists of a 3-tube chassis, a speaker-microphone, and a selector switch panel. The parts are installed in a wooden cabinet. A combination volume control and ON-OFF switch is mounted directly below the selector switch panel. The pilot light is illuminated at all times when the switch is on.

A 3-position switch at the center of the cabinet front controls talk-listen or idle position. The speaker microphone is mounted inside the cabinet behind the grill on the front panel. A junction box, used for interconnection to remote stations is attached to the chassis by flexible cable. An a-c power cord is attached to the chassis.

The switch panel consists of the selector switches (12 for the model shown), a space above each switch for identifying the station, and an annunciator for each switch. (All intercoms are not equipped with annunicators.) The switches have three positions: OFF, ON, and a third position to operate annunciators on a remote annunciators master station unit.

The annunciators are solenoid plungers mounted above each station selector switch. When the button atop a remote speaker microphone is depressed, or when a switch on a remote master unit is pressed down, a buzzer at the master station sounds, and the annunciator above the switch for the calling station springs outward. The annunciator remains out until the call is answered; it should be pushed back to its normal position at the same time that the selector key is raised to answer the call.

The talk-listen lever is a 3-position switch. The three positions are IDLE, LISTEN, and TALK. Under normal operating conditions, the lever should be left in the idle position. The idle position should be used to determine whether a station to be called is in communication with another station. Leaving the lever in the idle position, flip the selector of the station that is to be called. If no other station is conversing with this station, press the lever to the talking position and speak into the master station. If the system has only one master unit, you may press the lever into the talk position without going through the idle position, since remote speaker microphone units cannot communicate with one another.

INSTALLATION PROCEDURES

Any combination of master stations and speaker microphone units up to the capacity of the master station can be used. Where it is not

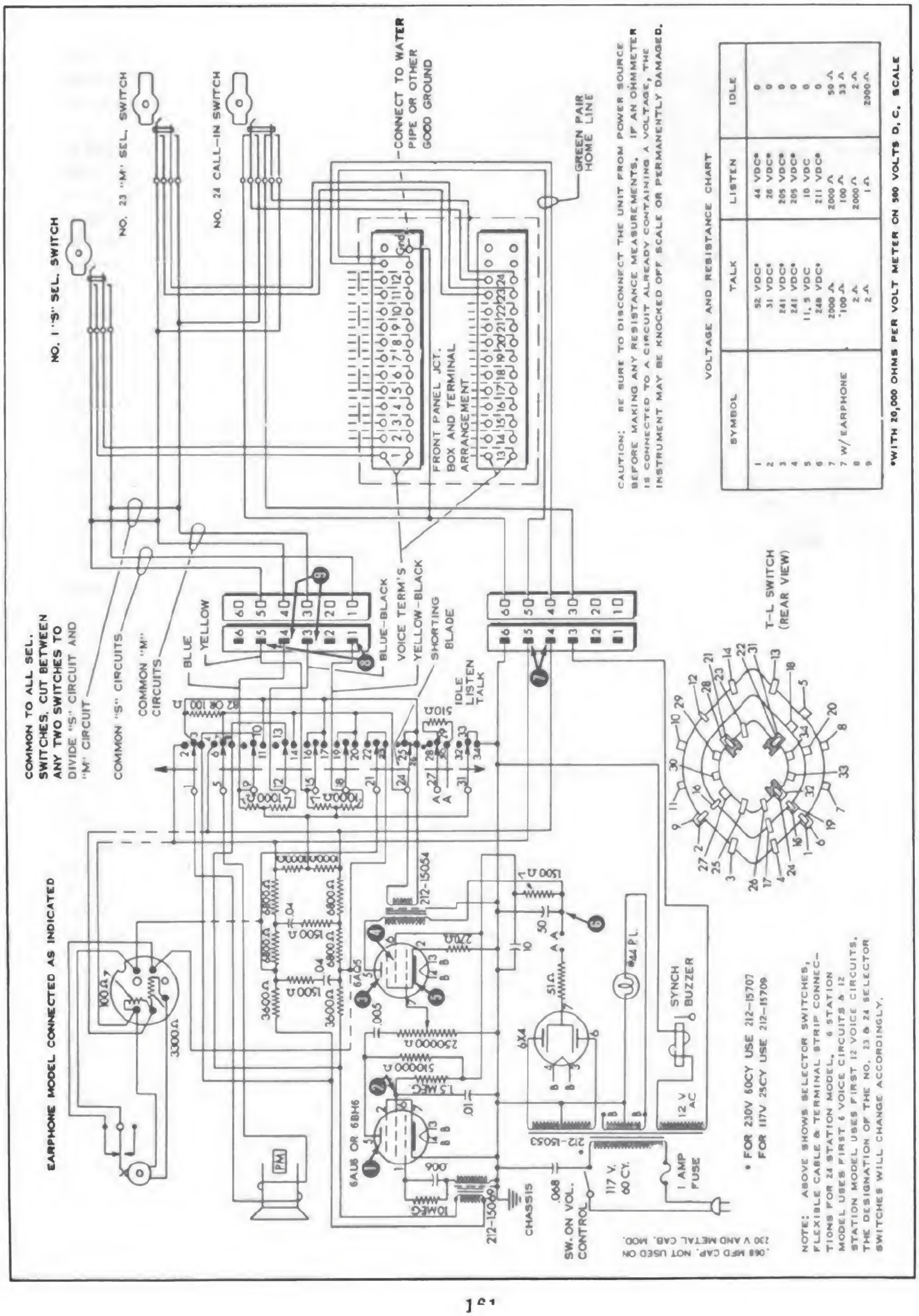


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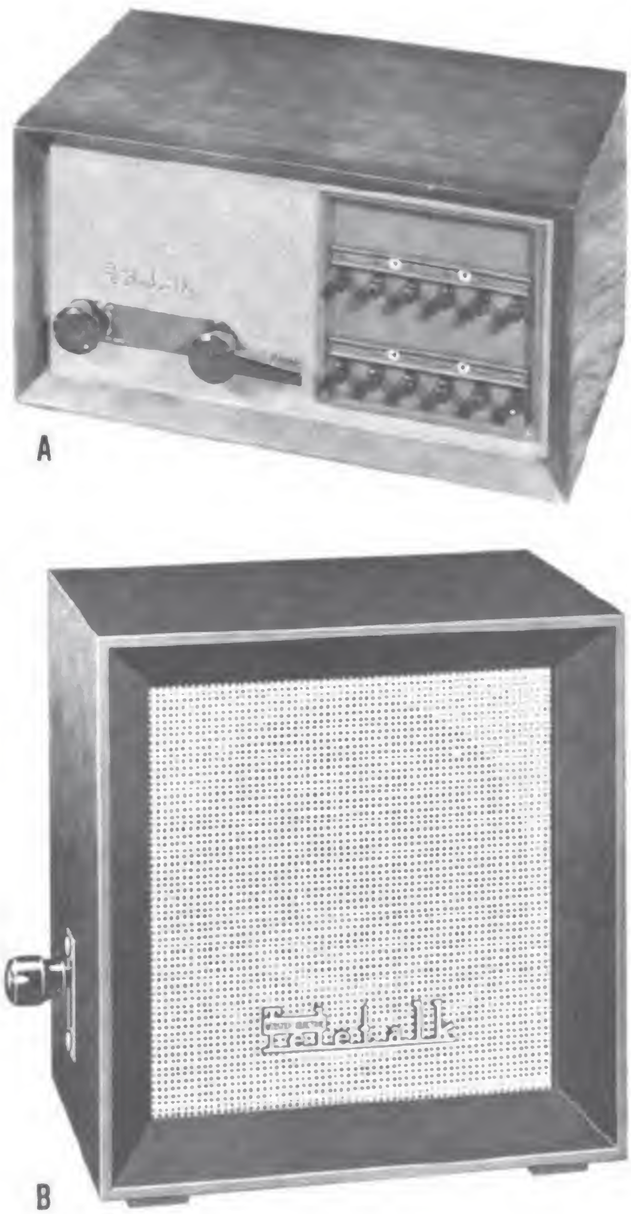
Figure 7-26.—Intercom Model 700 wiring diagram.



A. Master station.
B. Remote unit.

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Figure 7-27.—Intercom Model 700 series set.

necessary for remote stations to communicate among themselves, only one master station will be installed; this is the usual case. (Figure 7-29 shows a circuit with all remote speakers connected to call-in line.)

Install the master station within reach of a 110-125 volt, 50-60 cycle a-c power outlet. The master station and the speaker microphone units should be placed on the desks or in the working spaces of the personnel who will use them. If some of the units are installed outdoors, take the necessary precautions to protect them from adverse weather conditions.

The size of the wires to be used in making connections between units is governed by the length of wire. For the voice lines, No. 22 to No. 19 twisted pair wire is used. The maximum wire resistance permissible will be stated in the operating instructions. For the model shown in figure 7-26, the maximum resistance is 50 ohms per pair. The amount of wire determines the wire size to be used. No. 22 wire gives a resistance of 32 ohms per 1000 feet, and No. 19 wire gives a resistance of 16 ohms per 1000 feet. The larger sizes of wire (lower number) should be used when great amounts are necessary to connect the units.

The wire resistance of the annunciator lines must be kept below 15 ohms per pair. Normally No. 14 wire (which gives 4 ohms per 1000 feet) or No. 16 wire (which gives 8 ohms per 1000 feet) is used.

All connections to a master station unit are made on the junction box; the wires are soldered to their respective terminals on the terminal strips. Connections to the speaker-microphone units are made by connecting the wires to terminal screws on the bottom of the unit. On models having annunicators, the annunicator wires are attached to the pushbutton terminal block.

Be sure that the interstation wires do not cross hot pipes. The wires should never be placed where they are in danger of being covered by water.

After the wiring is installed, check the resistance with an ohmmeter. Make certain that the maximum permissible resistance is not exceeded and that there are no opens, grounds or shorts.

MAINTENANCE AND REPAIR

Many of the maintenance and repair instructions that apply to switchboards apply equally to intercom systems. In general, preventive maintenance techniques consist of five steps:

1. Feel
2. Inspect
3. Tighten
4. Clean
5. Adjust

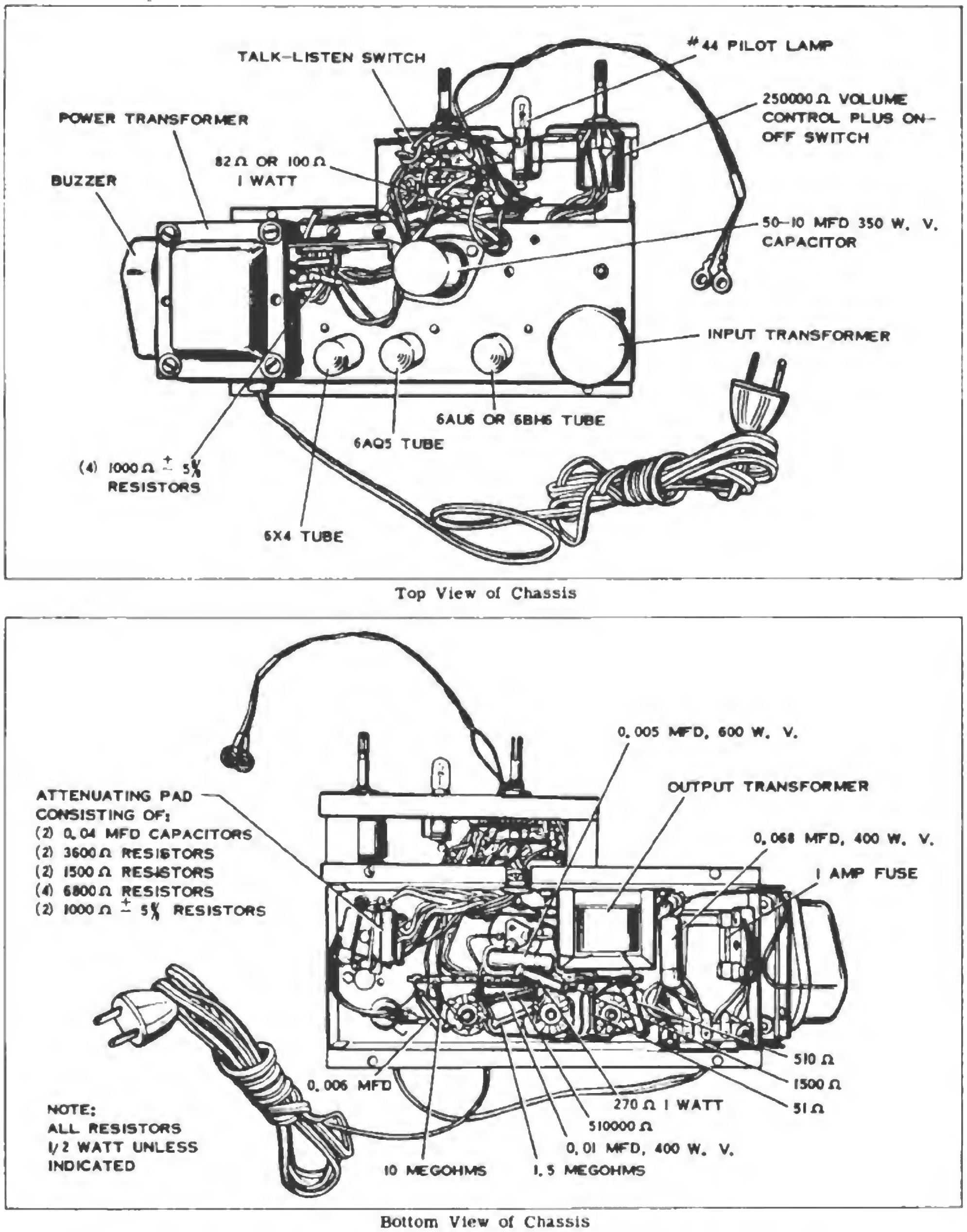

Figure 7-28.—Chassis of a Model 700 intercom master station.

The feel operation is necessary to check and determine if electrical connections or bushings are overheated. Feeling indicates defects requiring corrections.

Inspection is, of course, the most important operation in the preventive maintenance program. Check for the same four conditions that you check on a switchboard:

1. Overheating
2. Placement
3. Cleanliness
4. Tightness

The tightening, cleaning and adjusting operations are self-explanatory.

Table 7-2 lists the most common types of troubles that you are likely to encounter in an intercom set.

Components in intercom sets are readily accessible and may be easily replaced if found

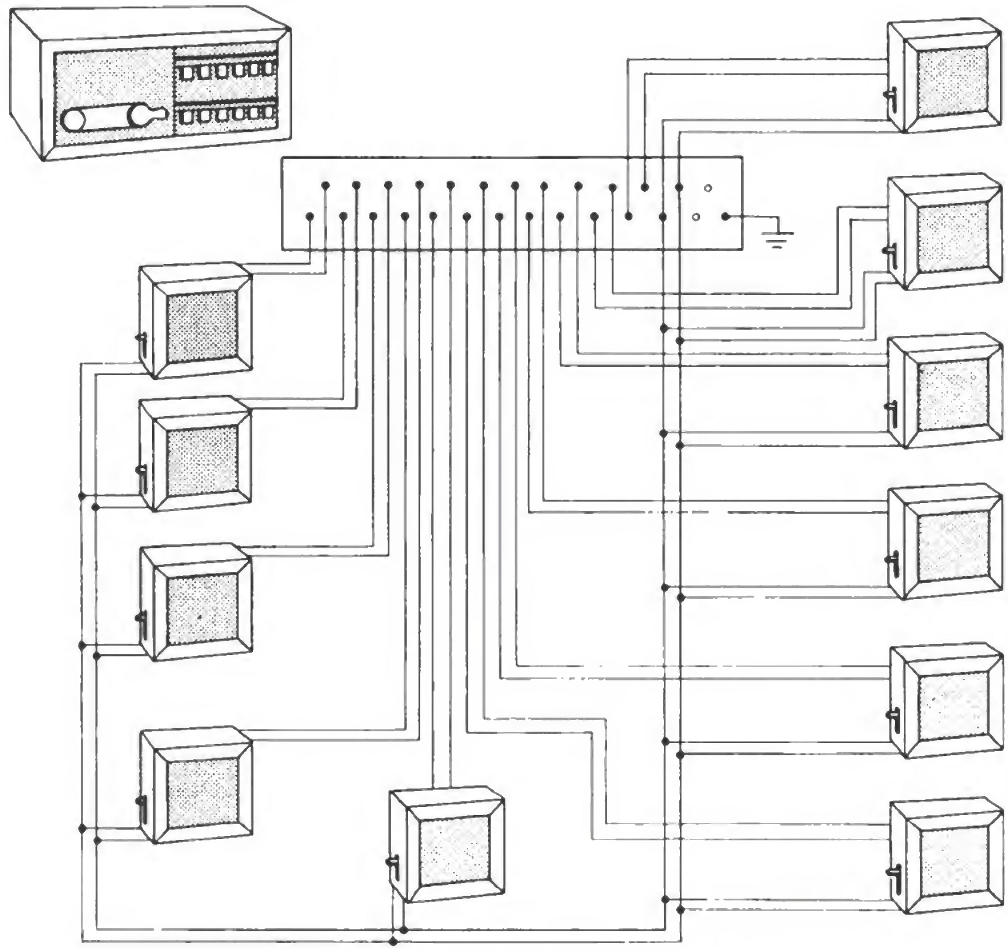

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Figure 7-29.—Twelve station intercom system layout.

to be faulty. When a defective component such as a burned-out resistor or transformer, is located, remember that the cause of the condition may be in some other part of the circuit. If the cause is not located and corrected, the new part will be burned out in the same way as the one that was replaced.

TROUBLESHOOTING

When trouble develops in an intercom system which has been properly installed and has been operating properly, the fault will usually be in one of the units of the system rather than in the interstation wiring. If the fault is in the interstation wiring it can easily be traced because the units will usually operate properly on some branches of the system. Once a fault has been traced to some particular unit it can sometimes be located by sight or smell (burned out resistors and shorted transformers) but most faults must be traced by checking voltages and resistances.

In troubleshooting ALWAYS REMEMBER:

1. Noise or hum may be mechanical noises picked up by the microphone and amplified at the master station; or it may be caused by office equipment, or other external causes.
2. The majority of master station trouble can be traced to faulty tubes. Replace the tubes with a set of tubes known to be good before becoming involved in major trouble-shooting procedures.

Table 7-2. Troubleshooting Chart For Intercom System.

Trouble	Probable Cause	Remedy
1. Pilot lamp and tubes do not light when switch is on.	Power supply not on.	Test power supply.
	Defective switch on volume control.	Short out test.
	Poor connections in power supply.	Check circuit with ohmmeter.
	Tube filament failure.	Check tubes.
2. Low volume and distortion.	Defective tube.	Replace with tube known to be good.
	Defective filter capacitor.	Replace filter capacitor.
3. Unit operates properly but with 60-cycle hum.	Defective tube.	Replace with tube known to be good.
	Open or leaky filter capacitor.	Replace filter capacitor.
	Ground or leak in unit or in external wiring (hum occurs only when selector key is up).	Check from wire to chassis or ground with ohmmeter. Resistance should be over 100,000 ohms.
4. Pilot light operates and tubes light but unit does not operate.	Defective tubes.	Replace with tubes known to be good.
	"B" supply shorted or open.	Check circuits for open with ohmmeter.
	Open or shorted resistors.	Check all voltages.
	Loose or broken wiring.	Check by visual inspection.
5. Unit operates properly on some stations but not on others.	Open or short in interstation wiring.	Check interstation wiring with ohmmeter.
	Open contacts on selector switch.	Check contacts on selector switches and clean with dry-cleaning solvent.

Table 7-2. Troubleshooting Chart For Intercom System.(Continued)

Trouble	Probable Cause	Remedy
6. Feed back howl or hum.	Acoustical feed back from nearby unit.	Reduce volume.
	Input and output wiring too close.	Isolate circuits.
	Open filter capacitor.	Replace capacitor.
7. Distortion and low volume.	Open or leaky coupling capacitor.	Replace capacitor.
	Low "B" supply voltage.	Check supply voltage with voltmeter.
	Defective tube (exclusive of rectifier tube).	Replace with tube known to be good.
	Voice coil of speaker rubbing.	Replace speaker.

Before parts are unsoldered the position of the leads should be noted. If the part has several connections to it, each lead should be tagged. Care should be taken that other leads are not damaged by being pulled or pushed out of the way.

You should remind your crew of the following facts when they are to solder connections:

1. A carelessly soldered connection may create a new fault.
2. A poorly soldered joint is a very difficult fault to locate.
3. It is easy to allow drops of solder to fall into the set.
4. Drops of solder in a set may cause a short circuit.

These points should particularly be remembered when leads are being soldered on intercoms. This information, however, applies to soldering of all communications equipment.

PUBLIC ADDRESS SYSTEMS

During the early stages of an invasion, portable types of public address systems are used to amplify speech in the landing area. Small types are d-c battery powered and are completely self-contained. When great sound coverage over a high level of noise is required, a larger a-c portable type, powered by a gasoline driven generator is used.

At an established base, a public address system may be used for an auditorium, outdoor movies, or for camp communications. A talk-back type of system can be used for camp communications. Horns serving as loudspeakers can be placed at strategic locations around the base.

The talk-back type is seldom used. The system generally used for advanced base communications is a portable set consisting of a 100-watt cabinet-type amplifier, a dynamic (movable coil) microphone with heavy-duty floor stand, two 25-foot lengths of shielded microphone cable, and one 25-foot length of heavy-duty power cable. This system requires 100/125 volts a-c on 50/60 cycles.

The horns serving as loud speakers can be controlled individually or in any combination. The speaker can address only one station, a few stations, or all stations. A change-over switch is provided to allow signal input from either a microphone or a phonograph.

As with any electrical circuit, the wiring diagram provides the key for the proper wiring connections. Normally, No. 14 size wire should be used for wiring connections. The horn loudspeakers may be mounted on top of buildings, on poles, on speaker stands, or even in trees. Before making the location of the loudspeakers permanent, it is desirable to test for uniform loudness, for minimum echo, and for dead spots. Follow the recommendations of the manufacturer closely when you make the installation.

Trouble in a p-a system is frequently caused by loose cable connections or breaks in the cable shield. Before commencing lengthy tests, check for faults of this type. In soldering connections make sure that both metals are clean; the completed soldering job should be firm and durable. Faulty soldering can cause faults in the system that are very difficult to locate.

Serious troubles in the system require signal tracing equipment such as an audio-signal generator and an output meter or an oscilloscope. In testing the electric circuit, the most important point to remember is that the trouble should be localized and isolated. A careful study of the circuit diagram will save much unnecessary testing.

CHAPTER 8
TRAINING

TRAINING RESPONSIBILITIES

Opportunities for conducting training are unlimited. Training includes all of those formal and informal situations where individuals or crews are given instruction toward the solution of:

1. Immediate problems related to the readiness of the unit to perform its current mission, or the problems related to the readiness of the members of the unit to do their jobs with a high degree of skill.
2. Long-range problems related to the readiness of members of the unit to qualify for advancement in rating, or the problems encountered when members of the unit need training for future jobs requiring skills not now possessed.

In most battalions, wherever problems are discovered, it has been found that many of them can be solved by training. Even so, training is not a wait and see responsibility. It must go on at all times. For example, training is conducted while your battalion is at the home port; and upon deployment, the embarkation and debarkation procedures are, for the most part, training exercises. Construction projects undertaken while deployed also have a valuable training function. All of this training serves a long-range preparedness need as well as the need for various skills on the immediate construction project.

IMMEDIATE AND LONG-RANGE PURPOSES OF TRAINING

Training men in advance of deployment to do a specific job has both immediate and long-range benefits. Advance planning sometimes provides for such training. For example, the detachment of Seabees assigned to Operation Deepfreeze II (Antarctic Operation) underwent a rigorous advance training program which included physical exercises, field marches, safety and survival lectures, and special schooling in coldweather work techniques.

A study of the job skills required to do a future job may be the starting point for training. After you have made such a study, taken an inventory of the skills the men in your crew now possess. You can easily see whether the required skills match the available skills. When you cannot match the skills, you may have to conduct training sessions in order to bring the men up to the proficiency required to do the job. In some cases you will have to conduct refresher training; in other cases you will have to provide instruction in new techniques for doing things.

At the job site, for example, much of the training will be for the purpose of helping a man become more versatile, so that he can fill more than one job. One man might be an excellent splicer, but a poor mechanical and/or soldered electrical connections man. On the other hand, some of the training may be to help him do his present job better. To do your own job properly, you must study and work continously to improve your own techniques. You must analyze work procedures and find ways to combine operations to shorten the time required to do a job. Having done this, you must train your men in the new procedure.

Some training that goes on in a battalion is of a general nature not related to the job at hand. Training for advancement in rating, including cross-training, is a good example of training of a general nature which obviously has long-range benefits.

ADMINISTRATIVE GUIDELINES

Most training is best administered through the company organization, with senior petty officers of the company carrying out the training programs under the company commanders. The training should be consistent with the following guidelines:

1. It must be closely integrated and coordinated with the daily operations of the battalion. The plan and organization for training must not interfere with the essential construction functions.

2. Concentration on the construction schedule should not be so extreme that opportunities for training are overlooked; some types of training may even have an immediate beneficial effect on the progress of the job.

3. Maximum advantage should be taken of the opportunities to derive training benefits from routine operations.

CATEGORIES OF TRAINING

Categories into which training is classified, at least for the purposes of this chapter, are ON-THE-JOB training and FORMAL training. These categories, together with hints for conducting such training, will be discussed briefly in the remaining pages of this chapter.

ON-THE-JOB TRAINING

On-the-job training is mainly for the men who already have skills and are on the job. It is usually controlled through daily job assignments.

In general, the objectives of on-the-job training in the Navy are: to broaden a man's work experience, to improve his work methods and increase his production, and to provide training for him in the application of basic skills to specific work assignments. For example, future work plans require installation of pole lines where the transformer bank is connected. The lines are hot. Maybe you have just joined the battalion and you are not sure of the capabilities of your men, or perhaps you believe that some men need additional training in the use of "hot sticks."

The following on-the-job approach is simple. The next time service can be interrupted on a line that needs repairing (or installing), a good idea is to deenergize it, and then assume, for the purposes of training, that the line is hot. Direct the men to install the pole and make the connections under hot line conditions. This makes it possible to make a check on a man's skills as well as his understanding and proper observance of safety precautions.

Other jobs can be undertaken on the job primarily for their training value. For example, the proper bending of conduits into 90° elbows, offsets and saddles requires a lot of practice. This can be accomplished with scrap leftover pieces of conduit during occasional slack periods, when advance work, preparatory work, and fill-in work can be scheduled. This is not busy work, nor is it wasted effort. As a matter of fact, it will probably result in the saving of many feet of conduit that may otherwise have been improperly bent.

As a usual thing, since on-the-job training is in the production environment, it will be your job as a CEC, to be directly concerned with supervision. You will undoubtedly observe subject matter areas where a man requires additional instruction but where the area of instruction is not of a type that can be conducted on the job. Reading blueprints or making mathematical calculations are examples. In such cases, formal training situations will have to be planned. Planning for this type of training should be coordinated, however, by the battalion training officer.

FORMAL TRAINING

Training requirements which grow out of a job, but which cannot be taught on the job, may require a formal, group instructional setting. It generally takes place during regularly scheduled training periods during the work day, and it may or may not be voluntary on the part of the trainees participating. Such training usually is in a group or classroom instructional setting.

Broken down as to subject matter, formal training may be arbitrarily divided into two areas:

1. Subject matter required for advancement in rating. Here the instructing petty officer conducts training in general subject matter areas such as mathematics, blueprint reading, or basic electricity. In this training situation men from other Construction Ratings will also likely participate, since knowledge in mathematics, for example, is a requirement for several ratings. At other times, in connection with advancement in rating, cross-training is required. Here the CEC instructs men from service ratings in subjects required for the general rating. And still at other times, he may lecture and demonstrate to CE strikers on subjects such as electrical theory, power distribution, or telephone cable splicing.

2. Subject matter required for the solution of an immediate problem which may or may not have a bearing on rate training. The predeployment training of the detachment that participated in Deepfreeze Operation II is an

example. Group training where work simplification is necessary to make work schedules mesh—as when Builders, Steelworkers and Construction Electricians working on a common job run into dead time because one of the groups, or perhaps all three, are using cumbersome work techniques—is another.

HINTS ON CONDUCTING TRAINING

Restudy the training chapters in Military Requirements for Petty Officers 3 and 2, NavPers 10056 and Military Requirements for Petty Officers 1 and C, NavPers 10057 for guidelines for conducting training.

CLASSIFICATION OF SUBJECT MATTER

The Navy classifies its subject matter into three types: KNOWLEDGE, SKILL, and ATTITUDE. How you organize and conduct training depends upon what you want to teach. There is no "best" method. Training on-the-job is different from training in a formal, classroom situation, although there are some common techniques.

Knowledge Type

Knowledge-type subject matter is that which is taught to build up a store of useful facts, principles, theories, and so on. This type of subject matter is usually presented in a formal training situation. Instruction in a-c and d-c theory, for example, is knowledge-type subject matter. Common properties of electrical circuits is knowledge-type subject matter. Instruction in these, and other such subjects, would probably not begin on the job. After theory and principles are developed, however, their application might well be demonstrated either under formal conditions or in an on-the-job training situation.

Self-study by men of the Navy Training Course, Construction Electrician 3 and 2, NavPers 10636, is an example of men acquiring knowledge-type subject matter. The correspondence course available to them carries questions to determine how well they have gained information.

Skill-Type

A skill-type subject—mental or physical—is subject matter taught to help a man acquire an ability to perform required jobs with ease, speed, and precision. The teaching approach to this situation would, of necessity, be quite different from a knowledge-type instructional situation. Skill-type instruction usually is the next step in instruction following the presentation of knowledge-type instruction; or it may be instruction born of necessity on the job. And, additionally, it may be skill training planned by a CEC to see if a striker who has read a chapter in Construction Electrician 3 and 2, NavPers 10636, on telephone cable splicing can actually splice a cable.

If need for instruction in a skill-type subject grows out of a job, it may be taught on the job, or it may require instruction, at least for introductory information, under formal conditions. Later, for application and practice, an on-the-job training situation may be appropriate. Teaching the use of "hot sticks" (referred to later) is an example. In another example, a CEC might, in the absence of a CET striker, teach a CEW the on-the-job skills necessary to make minor repairs to telephone wiring, subsets, and signal circuits.

Attitude Type

Attitude-type subject matter is selected and taught to create proper feelings, understandings, respect, and the like. Safety precautions could be attitude-type; so could military courtesy. Both might be knowledge-type, too. "Seabee Accomplishments" is an attitude-type subject. Attitude-type subject matter can be organized in the same manner as knowledge-type subject matter.

CARRYING OUT AN INSTRUCTIONAL PROGRAM

The two categories of training (on-the-job training and formal training) have been introduced, and the three types of subject matter have been described. Now for some practical ideas of carrying out an instructional program. Two situations are assumed. In one it is proposed to use, purely as a point of departure, the qualification for advancement in rating which

requires you to instruct in a-c and d-c theory. The other is training to solve, for example, the problem referred to earlier where it was observed men did not have sufficient skill to use "hot sticks" in working hot lines.

The presentation and suggestions about to follow are included to give you ideas of how you might fulfill your teaching responsibilities. The hints given are not to be construed as standards one is bound to observe.

Under the first assumed training situation—to fully satisfy your observers that you can instruct in application of a-c and d-c theory—may take from 8 to 10 hours of instruction time, plus a considerable amount of planning time before the instruction starts. Under the second assumed training situation of using "hot sticks" the time required will depend upon the receptiveness of the trainee to learn and upon the frequency of the opportunity for training.

During the planning stage of any training, the following actions on your part are necessary:

1. Ascertain what the training requirements are.
2. Prepare an outline of instruction.
3. Determine the training aids, materials, and equipment that you will use.
4. Prepare lesson plans, lecture notes, and instruction sheets to complement the instruction.

Outlining the Instruction

Having learned what the training requirements are, perhaps the first bit of planning is in connection with the preparation of a complete outline of the scope of the instruction. One method of preparing such an outline is to make a quick survey of the subject matter field. Review the Navy Training Courses bearing on the subject. After this survey, broad areas of instruction will begin to shape up in your mind. For example, to teach the practical application of a-c and d-c theory, some CECs have demonstrated their ability to teach by using the following areas of instruction:

1. Simple and complex circuits
2. D-C series and parallel circuits
3. D-C compound and bridge circuits
4. A-C theory, and fundamentals

A simple outline for the teaching of "hot sticks" might look like this:

1. Need for use of hot sticks
2. Brief history of hot sticks
3. Description
4. Demonstration of use of hot sticks
5. Practical application

Within each of the broad areas identified for training, the next step is to develop topical outlines, and arrange them in a systematic manner, so that each topic and subtopic within the outline rests securely upon information developed in a preceding topic. For example, in the first assumed training situation, you may have arbitrarily decided that one topic within the broad topic of "D-C Series and Parallel Circuits" might be "Direct Current Circuits." Another might be "Ohm's Law." A partial outline of instruction might appear as follows:

1. Direct current series circuits
   a. Series circuit connections
   b. Resistances in series
   c. Current flow in series circuits
   d. Voltage in series circuits
   e. Demonstration of series circuits
      (1) Series circuit resistance
      (2) Series circuit current
      (3) Series circuit voltage
      (4) Open circuits
      (5) Short circuits
2. Ohm's Law
   a. Ohm's law in simple and complex circuits
   b. Ohm's law in series circuits
   c. Ohm's law demonstrated
   d. Experiement in Ohm's law

After subject matter is selected, but while a detailed outline is being prepared, make a list of all training aids, special devices, equipment and tools which will be useful in teaching. If instruction is to take place at a time in the future which permits ordering training film, transparencies, and other training devices, include these in the list.

Before, after, or concurrently with the development of the training aids and equipment list, or even the outline of instruction for that matter, make also a list of all texts and instruction books that are to be used in preparing for and in presenting the lessons.

Based on the outline of instruction, the instructor next develops lesson plans for specific training periods.

Preparing Lesson Plans, Instruction Sheets, and Lecture Notes

LESSON PLANS.—A lesson plan is the blueprint the instructor uses to teach a specific topic or lesson. When the planning previously

discussed has been accomplished, a lesson plan is not difficult to prepare. Lesson plans can be in many forms. The following main parts of a lesson plan have been used in Navy training for a good many years: title of topic, objectives, training aids, references, introduction, presentation, application, summary, test, and assignment. A format for use in preparing a lesson plan is given in figure 8-1.

It will be observed in figure 8-1 that the instructor is cued to do certain things at certain times. Directly opposite or immediately below various points in the outline of instruction in the presentation section of the lesson, the instructor includes methods he will use to teach, questions he will ask, or problems he will work.

It is presumed that when one teaches he is thoroughly trained and already has acquired the technical information he expects to impart to the class. He may, nonetheless, in advance of his presentation, prepare his own lecture notes which will parallel, as necessary, the points in his lesson plan. Figure 8-2 shows a partial set of lecture notes on the Electron Theory which the instructor might want to prepare and refer to as he teaches.

INSTRUCTION SHEETS.—To augment the teaching and to complement the lesson plan, the resourceful instructor may enrich his teaching by using instruction sheets.

Several types of instruction sheets are used in Navy training:

1. Information sheets
2. Job sheets
3. Assignment sheets

These sheets are instructor made and are designed to assist the trainee in the learning process. They may be planned for in the lesson plan as part of formal instruction, or be used in a self-study situation where the time the instructor can give individual instruction is limited. Information sheets are developed when a knowledge-type subject has been introduced and the instructor desires to give the trainee information that he must know in order to do a specific job, or jobs. Information sheets may be used to introduce general or related information. Figure 8-3 shows an information sheet on D-C Series Circuits; and figure 8-4 shows an information sheet on hot sticks.

Job sheets may be used after you have provided theory and have demonstrated how a skill-type job is to be performed. Job sheets may be used in class as an integral part of the lesson, or they may be used in a self-study situation where the instructor is available for consultation and can make frequent checks. Job sheets, as such however, are not generally used to teach a man how to do a job. Rather they provide the trainee with a directed means of applying the knowledge he has gained. As for example, job sheets may be prepared to check a man out in performing calibrations, adjustments, tuning, testing, and troubleshooting. Job sheets ought to include situations where the user makes mental decisions similar to those he will make while maintaining and/or troubleshooting his equipment. Figure 8-5 will give you an idea of the format and contents of a job sheet that might be used in training in the application of a-c and d-c theory; figure 8-6 shows a job sheet for using hot sticks.

Instruction that is of a continuing nature requires that assignments be made. Assignments, of course, can be made orally and can be of a general nature, but more discipline and direction can be put into the learning process when frequent use is made of prepared assignment sheets. Assignment sheets are particularly helpful in self-study situations. For example, figure 8-7 might well have been prepared for use for a home study assignment, after the instructor had introduced Ohm's law and had solved several problems.

Conducting Cross Training

Cross-training—that is, preparing men in service ratings for advancement to the general rating—is an important part of your training job. Before any of the CE2s (CEP, CES, CET, or CEW) can be advanced to CE1 they must all be familiar with the duties of the other service ratings.

One preliminary step you can take toward fulfillment of your responsibility in cross-training is to make a careful study of the qualifications for advancement in rating found in Appendix I of this text. Rule off a piece of paper into columns headed as follows:

Common quals	CEW	CEP	CET	CES

Study the quals, and list those in which all service rates must be checked out, and list them in the first column. Obviously, quals in

SUGGESTED LESSON PLAN FORMAT

I. TOPIC ______________________________ QUAL. NUMBER ________

II. OBJECTIVES (of the lesson)

III. MATERIALS

List references, training films, other training aids, shops, and equipment to be used in preparing and presenting the lesson.

IV. INTRODUCTION

List points that will arouse trainees' interest and make them want to learn. Include what you expect trainees to accomplish during the training period, why the lesson is important, how, when, and where the trainees will apply it.

V. PRESENTATION

Make a complete outline of all parts of the lesson in the order in which you will present them. Include material from any pertinent job or subject matter analysis.

Indicate directly opposite or immediately below the various statements in your outline the methods you will use to teach them. For example, some of your typical notes will be: Ask the following questions; draw this diagram on the blackboard; demonstrate how to use this tool; use chart No. __ to illustrate this principle, etc.

List questions on key points to be asked in order to stimulate trainee thinking and to determine trainee understanding and learning.

VI. APPLICATION (by the trainee)

Indicate in your outline the activities that you will have the trainees actually do during the lesson to apply it. Typical notes could include: Have all trainees solve the following problem; select a trainee to assist in demonstrating this operation; have all trainees perform training in the practical factors where required.

VII. SUMMARY

Recapitulate main points to strengthen the instruction.

VIII. TEST

Describe here the means for determining the effectiveness of your instruction. A fairly reliable estimate of trainee understanding and achievement can be obtained by judicious oral questioning and by close observation throughout the lesson. Short oral, written or performance tests provide an additional check on trainee learning.

IX. ASSIGNMENT

For maximum learning, it is desirable to give trainees a work assignment for the next lesson. Be sure to include what, how, when, and why for every assignment that you make.

Figure 8-1.—Suggested lesson plan format. 26.132

LECTURE NOTES

A. Electron theory

1. Molecule

Is the smallest possible particle a substance may be broken down into and still retain its physical identity. Molecules can be further broken down into atoms.

C. Current electricity

Current electricity is electrons in motion. If we cause electrons to flow from one point to another, an electric current exists between these two points. In order that current may flow we have a conductor.

1. Direct current

Is a steady flow of electrons through a conductor in one direction ONLY.

a. Sources

(1) Batteries

(2) Direct current generators

(3) Rectifiers

2. Alternating current

A conductor carrying alternating current electricity has electrons passing through it in one direction for a very short period of time, then the direction of electron flow is reversed, and the electrons flow through the conductor in the opposite direction for the same

Figure 8-2.—Lecture notes that may be used to complement the lesson plan. 26.133

INFORMATION SHEET

D-C SERIES CIRCUITS

INTRODUCTION

D-c series circuits, the simplest type of electrical circuit you will encounter, must be learned first.

A thorough knowledge of d-c series circuits will aid in understanding current flow and polarity of voltage drops and voltage divider networks in future circuits.

REFERENCES

a. NavPers 92022, Basic Electricity, vol. 2
b. NavPers 10086A, Basic Electricity

INFORMATION

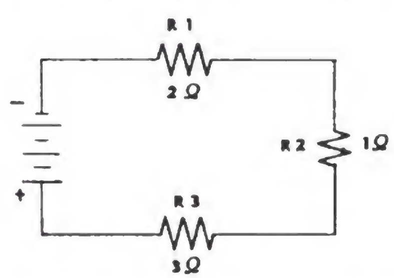
A series circuit is so designed that the current has only one path from the negative side of the source to the positive side. The current at any point in the circuit is the same as at any other point at a given time. This is true because there is one path only for the electrons to follow, and the same number of electrons that leave the negative terminal must be returned to the positive terminal, regardless of what the source may be (battery, generator, power line - - -).

The total resistance in a series d-c circuit is the sum of all the resistances, and the current is the same through any of the resistances.

The voltage will divide throughout the circuit proportionately with the size of the resistance. This can be proven by using Ohm's Law, E = IR, with E = voltage, I = current and R = resistance. The source voltage must be consumed or dropped in the circuit. Voltage drops have polarity identical to source voltage.

The polarity of a voltage drop can easily be determined. The end of the resistance closest the negative terminal will have negative polarity with respect to the positive terminal, and the end nearest the positive terminal will be positive with respect to the negative terminal. This is true because electrons flow from negative to positive, and in order to have current flow, a difference of potential must exist.

Let us take a simple circuit and see how the voltage divides.



First find total current. Ohm's Law says $I = \frac{E}{R}$. This being a series circuit we know that

Rt - R1 + R2 + R3
Rt = 2 Ω + 1Ω + 3 Ω
Rt = 6 Ω .

We also know the current is the same throughout the circuit. Therefore, we can easily find I, using Ohm's Law $I = \frac{6V}{6\,\Omega}$

I = 1 amp.

Figure 8-3.—Information sheet: d-c Series Circuits.

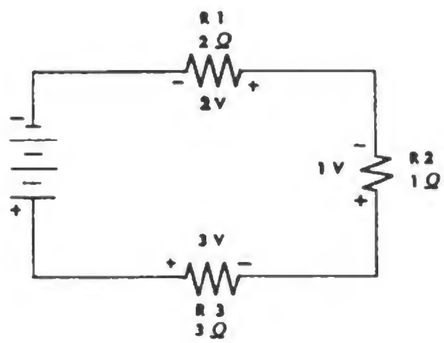
26.134.1

The voltage drops are proportional to the size of the resistances. Now apply Ohm's Law and see how the voltage is dropped. First, find the voltage dropped by R1.

E1 = I x R1	R2	E2 = I x R2	and R3	E3 = I x R3
E1 = 1a x 2Ω		E2 = 1a x 1Ω		E3 = 1a x 3 Ω
E1 = 2V		E2 = 1V		E3 = 3V,

thus, Et Et = E1 + E2 + E3
Et = 2 + 1 + 3
Et = 6V.

To determine the polarity of the voltage drops, use the rule stated earlier. The end of the resistance nearest the negative terminal is negative with respect to the positive terminal, and the end nearest the positive terminal is positive with respect to the negative terminal. Thus,



Another thing to be considered in a d-c series circuit is power dissipation. When there is current flow power is used. The Ohm's Law formula for finding power, P = I x E where P = power in watts, I = current in amps and E = voltage. Thus, a circuit with 1 amp of current and 6 volts will consume 6 watts of power, P = 1 x E
P = 1 x 6
P = 6W.

Other forms of Ohm's Law for power are $P = I^2R$ and $P = \frac{E^2}{R}$.

Remember, that to have current flow there must be a complete path from the negative terminal to the positive terminal. If a lead breaks or a resistor burns out, no complete path is available, and therefore no current flows. The circuit becomes inoperative until repairs are made that will restore the path for current to flow.

When there is more than one path, current always seeks the one of least resistance. If there exists a path from the negative to the positive terminals that would bypass the resistors the current would use this path. This action would cause "a short circuit," making the circuit inoperative. Steps must then be taken to remove this path to restore proper operation.

One more thing to be considered is Kirchoff's Law of voltages, which states that the algebraic sum of all the voltages in any complete electrical circuit is equal to zero. In other words, the sum of all positive voltages must be equal to the sum of all negative voltages. For a thorough explanation of Kirchoff's Law of voltages, read page 58, and column 1 of page 59 of NavPers 10086-A.

Figure 8-3.—Information sheet: d-c Series Circuits—continued. 26.134.2

INFORMATION SHEET

HOT STICKS

INTRODUCTION

As the use of electricity increases, the need for maintaining continuous service also increases. Rather than interrupting power service so that crews can work on cold lines, maintenance crews must learn to use hot line tools, called "hot sticks."

Men working on high voltage lines with hot sticks must be constantly aware of the danger involved, and consequently should use more caution than when working on low voltage or cold lines.

REFERENCES

a. Construction Electrician 3 and 2, NavPers 10636-D

BRIEF HISTORY

Hot line tools were first intended for work on lines up to 34 KV, but many linemen were hesitant to perform hot stick operations on what was then considered such a high voltage. Because of this fear, most of the men were unwilling to work with these tools on voltage above 22 KV.

As linemen began to realize that the hot sticks kept them at a safe distance from energized lines, they began to lose their fear.

In recent years hot line tools have been developed that will successfully handle hot lines having more than 345 KV (345,000 volts). Today there are very few jobs that cannot be performed hot.

The sticks shown as a part of this information sheet are commonly used. Hot line tools range from 3 feet to 12 feet in length.

Many hot sticks are made of wood. Sitka spruce, maple and oak have been found to have the most desirable characteristics. To prevent warping, the insulated sticks are laminated in two, three, or four sections, depending on the pole diameter. In recent years hot sticks are being made of plastic and fiber glass. These materials have a high moisture-absorption resistance, are more rigid than wood, and are highly resistant to abrasion and common solvents.

All hot sticks regardless of diameter have insulating qualities capable of withstanding 75,000 volts, 60 cycles, across each foot of pole length for a period of 5 minutes.

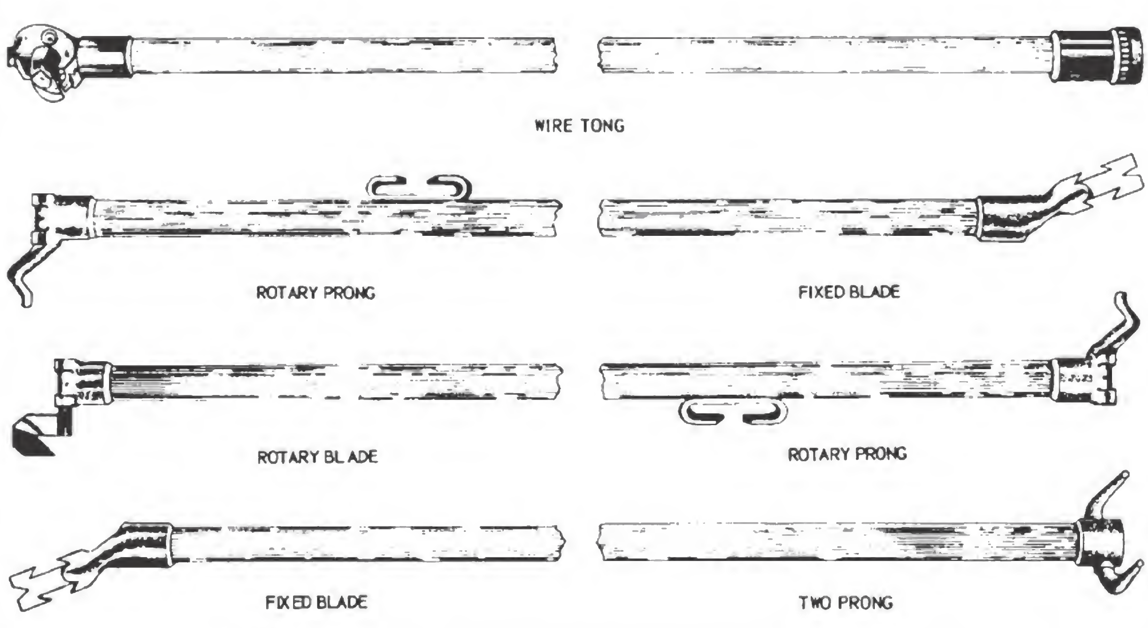


Figure 8-4.—Information sheet: Hot Sticks. 26.135

the first column represent knowledge and practical factors the men have already been checked out in, and except for refresher training, you will not be concerned with them. The remaining columns, however, you will be concerned with. As you find quals applicable to each of the service ratings, make an entry in the appropriate column. These columns become a guide to the subject matter for which you will be responsible in cross-training. If the man you are to train is a CEW moving up to the general rating, concentrate on the subject matter carried in the CEP, CET, and CES columns. In other words you are responsible for training in the areas and for the quals in which the man has not previously checked out.

After the chart has been made, inspect it in terms of subject matter for possible organization for training. Some of the material can be learned by study of the appropriate Navy Training Courses. Other subjects can only be learned by practical experience. Whenever possible, use an on-the-job training situation, but even here, as has already been pointed out, some formal training away from the job will probably be necessary. It is not likely, for example, you could teach a man the principles and theory of a-c and d-c motors by immediately assigning him to a job where he had to operate and service advanced-base-type generating equipment. Principles and theory are knowledge-type subjects and would have to be introduced under more formal conditions.

Cross-training is a term and there are no techniques of teaching which are peculiar to it. It must all be planned in advance, following the suggestions appearing earlier in the chapter.

JOB SHEET

TITLE: SERIES GENERATORS

INTRODUCTION: The purpose of this job is to familiarize the trainee with the connections and internal characteristics of the series generator. Many naval installations use compound generators, and knowledge of series generators will help electricians better understand the operation of compound generators.

EQUIPMENT:

1. Compound machine
2. Lamp bank
3. Four cone resistors
4. Multimeter with leads
5. 0-20 d-c ammeter
6. Two fuses and fuse pullers
7. Voltage tester
8. (2) $\frac{1}{2}$ x $\frac{1}{4}$ - 20 bolts with nuts

PROCEDURE:

1. Draw a diagram of a series generator, use correct terminal markings.

2. Check generator by hand, rotate armature, check for tight coupling.

3. Connect voltmeter to armature leads.

4. Rotate prime mover by hand and observe voltmeter deflection. Mark negative lead, "A1", positive lead "A2".

5. Connect generator as per diagram.

   NOTE: IF IN DOUBT AS TO CONNECTIONS, ASK INSTRUCTOR.

6. Install fuses in prime mover circuit, test fuses.

7. Start prime mover with VOLTMETER ON HIGH SCALE.

8. Check voltage

   a. Close load switches.

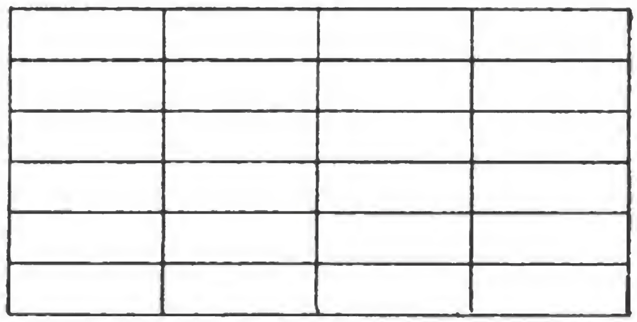
Figure 8-5.—Job sheet: Series Generators. 26.136.1

1. If voltage fails to build up, adjust neutral plane.
2. If voltage still fails to build up, reverse series-field connections.

9. Close load switches one at a time and plot voltage curve.

10. Open load switches. Record no-load voltage on graph.

VOLTS



AMPS

11. Secure machine, tag and pull fuses.

12. Disconnect all connections, but leave equipment at your station.

QUESTIONS:

1. ________________ is necessary to produce the small voltage deflection at no load.

2. The voltage _______________ as the current increases.

3. How do series-field coils differ from shunt-field coils?

REFERENCE: NavPers 10546, Electrician's Mate 3 & 2.

26.136.2

Figure 8-5.—Job sheet: Series Generators—continued.

JOB SHEET

USING HOT STICKS

INTRODUCTION

In your job as Construction Electrician it will often be necessary to work on lines where service cannot be interrupted. For example, if you are installing pole lines where the transformer bank is connected, you must learn to use "hot sticks." The purpose of this job sheet is to provide information that will assist you in learning to install a double "hot" tie on a single insulator. See the illustrations which are a part of this job sheet.

EQUIPMENT

1. The following hot sticks: fixed blade, two prong, rotary prong, and rotary prong

2. Simulated poles mounted with insulators

3. Tie wire

4. Lineman pliers

PROCEDURES

1. Make a 1-inch loop on the end of the tie wire and determine the length required for a minimum of six turns around the conductor. Then add the circumference of the insulator plus the additional length required for at least two turns at the middle of the double tie to secure it to the insulator. Add sufficient length and form a loop on the opposite end of the tie wire.

NOTE: On both double and single ties, tie wires should be attached to the insulator with a clockwise twist. The ties should also be wrapped around the conductor in a clockwise direction on each side of the insulator to prevent untwisting the tie wire where it is attached to the insulator.

2. Make up the other wire of the double tie the same length and place both tie wires around the insulator so that the looped ends are in opposite directions and parallel with the insulator groove.

3. Form the double ties closely around the insulator and secure them to the insulator with at least two turns made with lineman's pliers. After wrapping, each double tie should be tight around the insulator and still be in alignment with the insulator groove.

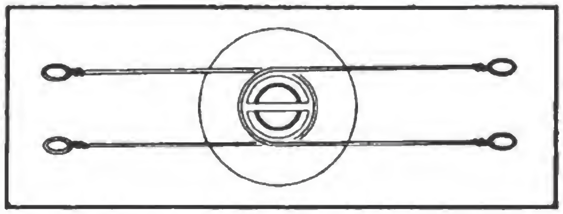
4. Shape the tie wires to form a letter "S" to prevent their extending too far from the insulator.

5. Secure the conductor in the insulator groove and hold it in place by applying downward pressure on the wire tong at the opposite side of the insulator where the first tie is to be made.

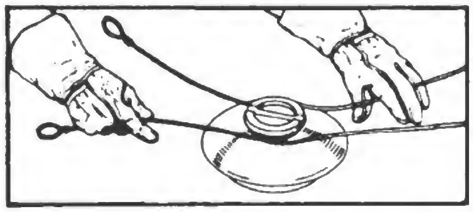
6. Using a ROTARY PRONG or other appropriate tie stick (see illustrations), rotate the two wires of the double tie progressively along the wire to produce a smooth, even tie. The ties should not overlap each other on the conductor.

7. After tying the conductor at one side of the insulator, tie the opposite side in the same manner. When the tie is completed, only the loops should extend out above the conductor.

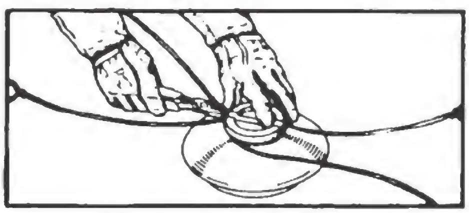
Figure 8-6.—Job sheet: Using Hot Sticks. 26.137.1



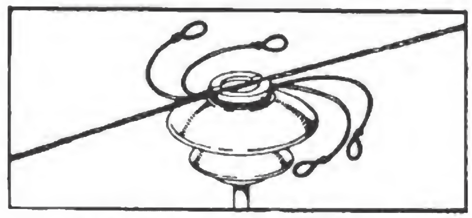
DOUBLE TIES IN PLACE ON INSULATOR



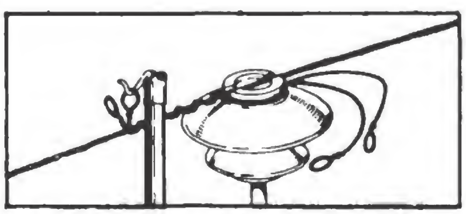
PULLING THE DOUBLE TIES TIGHT AROUND THE INSULATOR



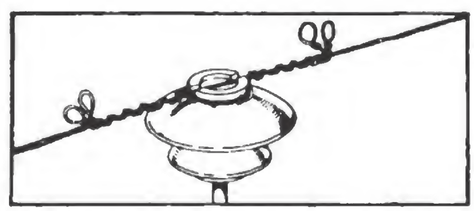
WRAPPING ONE OF THE TIES WITH LINEMAN'S PLIERS



DOUBLE TIES READY FOR TYING IN



TYING IN ONE SIDE OF INSULATOR WITH A ROTARY PRONG



BOTH SIDES OF THE DOUBLE TIE TIED IN

Figure 8-6.—Job sheet: Using Hot Sticks—continued. 26.137.2

ASSIGNMENT SHEET

Problems on Ohm's Law

INTRODUCTION

Ohm's Law for power calculations may be applied to a great many everyday problems wherever electricity is at work.

Consider one of the most common examples--that of the incandescent electric light. Incandescent lamps for use in constant-potential circuits in homes and factories are rated in volts and watts. How much current do they take? How much resistance do they possess? If high powered, they may draw several amperes; if low in wattage rating, they may take only a small fraction of an ampere.

PROBLEMS

Using the Ohm's Law formulas, solve the following problems:

1. What is the current rating of a 100-watt 120-volt lamp?

2. Use the answer to the first problem and find the resistance of this lamp.

3. How much does it cost to use this lamp 4 hours each evening for 30 days at 3.2 cents per kilowatt-hour?

4. How much would it cost to operate a window air-conditioner rated at 120 volts and 9.4 amperes in use 10 hours a day for 30 days?

Figure 8-7.—Assignment sheet: Problems on Ohm's Law. 26.138

CHAPTER 9
FOREMANSHIP

As a Construction Electrician First or Chief, you will have many responsibilities added to those which you have had at the second class level. The higher your pay grade, the more likely it will be that your main duties will consist of supervising rather than doing.

You must see that work is properly planned, that it is carried out in the proper way, that the proper records and reports are kept, and that safety precautions are observed. These duties and responsibilities are a phase of foremanship; another phase, training, is discussed in chapter 8 of this course.

Foremanship duties and responsibilities are of a continuing nature. Whether you are assigned to an MCB, a detachment, an amphibious construction battalion, or a public works department you will need to supervise men, delegate authority, coordinate operations, and train personnel. The type of activity to which you are assigned will determine just how you carry out your foremanship responsibilities. For the most part, the discussion in this chapter applies to MCB's assigned to an overseas base. The general principles, however, apply to other units also.

JOB PLANNING

To get an assigned job done in the proper manner and on time requires careful planning. You will need to know exactly what is to be accomplished, when it must be completed, the number of men available to do the job, and the amount of material required. In addition you will need to coordinate your work with men in other ratings. If, for example, the plans for a job call for placing conduit through the footings or within a slab deck, you must have your crew ready to place the conduit as soon as the Builders have completed the forms. The necessary information may be provided you in the form of standard drawings developed by the Bureau of Yards and Docks. In other cases, drawings may be provided by the local public works department or developed by the battalion engineering office. In any event, you must study all available information carefully to be certain that you understand all important aspects of the job to be done.

DETERMINING LABOR AND MATERIALS REQUIREMENTS

Preliminary planning is necessary to determine the amount of materials required for a job. This planning is accomplished by material takeoff teams, which operate under the engineering office. Material takeoff is highly specialized work which requires a knowledge of engineering drawings and specifications. You may be called upon to assist the takeoff team in making the material takeoff. The materials required for a particular job are listed on a bill of material (BM). Make certain that all materials required for the job on which you are working are listed on the BM; also make certain that they are available or that they are on order with the supply department. A careful check of the BM at an early stage of the job can save many a delay as the job progresses.

Either you or the officer in charge of the job will need to write up requisitions for materials on the proper forms. You will also need to check the delivery schedule of these materials in order to plan the work of your crew.

SCHEDULING

The various phases of a job must be carefully scheduled if it is to progress without delays. Generally speaking, the sequence of work assignments must correspond to actual construction operations. You must remember, of course, that some jobs take longer than others to complete. Thus, on a typical job, installing conduit may take considerably longer than installing underground service; you would need to use more men for the conduit than on the underground service if you needed to have these two operations completed about the same time.

It is important that every man assigned to you know his job within the framework of the

schedule. In some cases, a man may not be familiar with all phases of the job to which you assign him; for instance, a man may have had no recent experience working with explosion-proof wiring. If he is assigned to that phase of an installation job, knowing this in advance would give him a chance to brush up on this type of work. Making up the schedule in advance and posting it on the bulletin board or in some other prominent place is a useful method for keeping your men informed of their forthcoming assignments.

PLANNING FOR EMERGENCIES

Part of job planning includes planning for emergencies. Certain types of emergencies, of course, are beyond your control. Unexpectedly bad weather, enemy action and complete changes in plans are examples. You can prevent many emergencies from arising, however, by planning and forethought.

Whenever possible, you should check actual details of the job against the plans. Some details, such as ground conditions for underground conduit, cannot be adquately covered on the plans. Poor ground conditions might affect the location of manholes, thus creating a problem during job operations.

In making additions or changes to structures from old plans, it is particularly important to make certain that all parts of the plans have been followed during construction. Plans which were drawn up during emergency conditions, such as during World War II and the Korean conflict, were not always closely followed. One example will demonstrate this point. At an overseas base, World War II drawings were being used as a guide for installing additional wiring in an underground distribution system. The prints called for several spare conduits in a particular manhole. When the work crew began pulling wire through one conduit, they discovered that the conduit did not extend all the way to the transformer vault, although the print showed that it did. Two lessons are apparent from this example: first, plans should be checked against the existing conditions whenever possible; and second, any change from the plans you make during construction and installation – for whatever reason – should be shown on the master set of plans. Changes on the master plans will ensure that "as-built" drawings will be available for future use.

Personnel Problems

Failure to make allowance for personnel changes can slow down work or cause a complete stoppage. Some personnel matters, of course, are beyond your control. If a man suddenly becomes ill or goes on emergency leave, you will simply have to try to get a replacement for him or do some rescheduling. If a man is scheduled for leave or for detachment, however, and you do not take this fact into consideration when planning your schedule, the fault for any delay which results lies with you. In making up your schedule, consider military duties, special details, and similar factors that could affect work operations.

If you have a shortage of men for the job – and this not unusual – be certain that you assign them to best advantage, according to their skills and capabilities. Never ask for more men than you can use on a job; extra men get in the way of the workers.

Materials Flow

We have already mentioned that the bill of materials should be checked during the planning stage to make certain that all materials are available or are on order. Even with this check, there is sometimes danger of running out of material. This may happen when the rate of progress on the job has been considerably greater than anticipated or when materials have been unusually slow in arriving at the job site. If either of these conditions occur, notify the officer in charge of the project. He may appoint an expediter to see that materials get to the location where they are needed. Occasionally, you or one of your men might serve as expediter; in this case, you might hand carry a requisition through the supply chain to speed up delivery. This is strictly an emergency procedure, however. Careful advance planning will normally ensure an orderly flow of materials.

Machinery and Equipment

Machinery and equipment failures may result from numerous causes, many of which can be prevented. See that your men follow proper operating and maintenance procedures. Manufacturers' instruction books and local instructions should be strictly followed. There are

many examples that might be given of the misuse of equipment, but one is sufficient to illustrate the point.

Hydraulic benders are commonly used to bend 4-inch conduit. When fluid in the chamber is low, inexperienced men have been known to fill it with some fluid other than that recommended by the manufacturer – with motor oil, for instance. Improper fluids not only will not work satisfactorily, but may permanently damage the hydraulic system. Impress your men with the fact that they follow manufacturers' operation and maintenance instructions.

COORDINATION

You will need to plan ahead so that necessary equipment will be on hand to do certain work at the right time. On one particular job, for instance, there may be only one power threader, hydraulic bender, or similar item. You will need to check with other petty officers who are using this equipment to determine when such equipment will be available to do the job for which you need them.

A little coordination with other job supervisors will usually ensure that equipment is available when you need it.

A PRACTICAL EXAMPLE

To apply some of the principles so far discussed, let us set up a practical example. Assume that you are with a detachment assigned the job of constructing a four-unit building suitable as married enlisted men's quarters (MEMQ). The plans and specifications call for a rigid conduit job throughout, with electric heating, ranges, washers, and dryers as major appliances in each apartment. Let us assume also that the material and labor takeoff have been completed and that a job order number has been assigned. (See fig. 9-1.) On this job, you will have conduit in sizes from 3/4" to 4" and wire from #12 to 25 MCM or larger.

Make a list of the specific jobs that must be accomplished before the overall job is completed. Figure 9-2 gives this information in the left column, which is labeled Type of Work. To the right of this column, make several columns listing the dates on which you expect to accomplish specific jobs. Under each date column, place the number of manhours which you estimate will be required on that particular date. An X under a date indicates no work on that day. List at the bottom of the sheet the number of men and the amount and type of equipment required for the job. For this job, you will have six men available. List the names of the men and designate the lead man. Figure 9-2 shows the information which should be carried in the advance schedule.

Check to make certain that none of the men are scheduled for leave, transfer, or school.

In the early stages of this job, you may not need all six men; if this is the case, assign some of these men – perhaps two – to some other job under your supervision until the Builders get enough work on the MEMQ completed that you can use all six men.

Estimate the days on which you will need the pipe threader and the hydraulic bender, and check with the electric shop to be certain that they are available on those days.

You have now planned the job and set up a schedule. You cannot, of course, anticipate emergencies such as sickness and emergency leave. You have, however, gone as far as possible with your plans. When the work starts, you will need to make a daily work report as shown in figure 9-3. This report should account for the number of hours each man works per day on the job.

SUPERVISION

The term supervision may be defined in a number of ways. As used in this chapter, it means overseeing, directing, and inspecting the work of others.

Supervision, then, means working with people. A good supervisor knows how to get a job done by getting the most out of his men. This is the basic difference between a supervisor who is merely technically competent and one who knows how to get maximum production. It is extremely important, of course, for a supervisor to be technically competent in his specialty. Competence alone, however, will rarely get the job done when a person has to direct the work of others. As well as knowing and understanding the job to be done, a good supervisor must understand the capabilities of his men and must know the techniques of good supervision.

KNOW YOUR JOB

Your job is likely to vary with each deployment of the battalion. If the principal mission of

JOB CODES

JOB ORDER NO: 29 APPROVED BY: F. R. JACKSON LCDR. OPERATIONS OFFICER

JOB: M.E.M.Q. INSTALLATION: 14

PROJECT NO: 14261-694 TYPE WORK: ELECTRICAL

JOB CODE	
14-1	TRENCHING AND EXCAVATING FOR UNDERGROUND CONDUIT
14-2	INSTALLING CONDUIT 1½" AND LARGER
14-3	INSTALLING CONDUIT 1¼" AND SMALLER
14-3	PULLING WIRE #6 AND SMALLER
14-5	PULLING WIRE #4 AND LARGER
14-6	INSTALLING SWITCH, RECEPTACLE AND OUTLET BOXES
14-7	INSTALL SERVICE, INCLUDING PANELS AND MAIN SWITCHES
14-8	INSTALL LIGHTING FIXTURES
14-9	TELEPHONES, INCLUDING FEEDER AND TERMINALS
14-10	MISCELLANEOUS; CLEAN UP AREA, PROCURING MATERIAL
14-11	INSTALL SWITCHES, RECEPTACLES AND COVERS

Figure 9-1.—Job codes and list of jobs. 26.139

ADVANCE WORK SCHEDULE (IN M/HRS)

DATE: 4 Aug. 62

JOB: MEMQ.

SUPERVISOR: FRANKLIN CE1

TYPE WORK:	DATE / CODE NO:	AUG 7	8	9	10	11	12	13	14	15	16	17	18	19	20
INSTALLING CONDUIT 1¼"	7-A	24	24	24	24	*18	X	X	24	24	24	24	24	X	X
AND SMALLER															
INSTALLING CONDUIT	7-B	8	8	8	8	*6	X	X						X	X
1½" AND LARGER							X	X						X	X
PULLING WIRE	7-C						X	X	8	8	8	8	24	X	X
INSTALLING SWITCHES	7-D						X	X					8	X	X
AND RECEPTACLES							X	X						X	X
INSTALL MAIN SWITCH							X	X	16	16	16	16	16	X	X
AND LIGHTING PANEL	7-E						X	X						X	X
INSTALL SERVICE	7-D	16	16	16	16	*10									
(UNDERGROUND)															

*Scheduled personnel inspection.

EQUIPMENT NEEDED:

Pipe threader (Electric) to 4"
Hydraulic Bender (Pipe)

TOTAL NO. MEN: 6 (LISTED BELOW)

JOHNSON	CEW 2	FRANK	CN
BAKER	CEW 2	JONES	CN
NELSON	CEW3	FRANKLIN	CE1, LEAD MAN

Figure 9-2.—Advance work schedule. 26.140

DATE: 4 AUG. 1962

DESCRIPTION OF WORK

NAME	RATE	1" CONDUIT TO HEATERS	PULLING WIRE	3/4" CONDUIT - LIGHTING	1 1/2" CONDUIT RANGE	PULLING #6 WIRE TO RANGE	TRENCHING FOR 4" CONDUIT				
JOHNSON	CEW2	3	4	1							8
BAKER	CEW2	3	4	1							8
NELSON	CEW3				4	3	1				8
FRANK	CN				4	3	1				8
JONES	CN			1			7				8
FRANKLIN	CE1	1	2	1	2	1	1				8
Total		7	10	4	10	7	10				48

JOB TITLE: MEM.Q. SUPERVISOR: FRANKLIN CE1

Figure 9-3.—Daily work report.

18.5.1

the battalion is to construct housing, you are likely to be in charge of a crew installing interior wiring. On another assignment, the mission of a battalion may be to install portable electric power plants, including the distribution system. On some assignments, it may be necessary to install telephone systems. On most assignments, it is necessary to set up an electrical repair shop.

You may be in charge of a crew assigned to carry out any one of these jobs. To carry out the job properly, you must know exactly what is to be accomplished, deadlines for the job or portions of it, who will be your boss for the job, and the relationship with other projects. You will need to plan your part of the job with respect to materials and scheduling in the manner described earlier in this chapter. Unless you understand lines of authority, materials and equipment required, limitations of the equipment, and the capabilities of your crew, you are likely to have trouble in meeting your responsibilities.

KNOW YOUR CREW

It is not likely that you can do a good job unless you thoroughly understand the job to be done. Knowing your crew is as important as knowing the job. If a new CEW2 is assigned to your crew, you can be certain that he has been checked out in the practical factors for his rate and that he has passed the servicewide exam. Without investigation, however, you could not tell whether he is an expert in the use of test equipment or whether this is one of his weak points. Similarly, you could not tell whether he is almost ready for promotion to CE1 or whether he has just made his rate. His experience and capabilities will have a very important effect upon the type of assignment that he can handle best. Without checking, you cannot tell whether a new man is one to whom you can give very brief instructions and expect to find the job done, or whether you must keep a constant check on him. His traits may mean that you can assign him to a distant project where he can work under minimum supervision; or they may indicate that you should put him in a job where you can keep an eye on him and place a man who can work under less supervision on the distant project.

From the foregoing, it is obvious that a good supervisor needs to know the strong points and weak points of each crew member. You need to know your crew in order to make intelligent decisions about assignments, needed training, and recommendations for advancement in rating, among other things.

When you learn that a new man is being assigned to your crew, learn what you can about him; ask to see his record. Talk to him when he reports; find out what he has done and likes to do. Finally, observe him closely in various work situations; you will soon learn what type of person he is.

DELEGATING

One of the most common failings of a new supervisor is failure to delegate. It is natural to want to carry out the details of a job yourself, particularly when you know that you can do the job better than any of your men. Trying to do too much, however, is one of the quickest ways to get bogged down in details and to slow down a large operation. You will often be responsible for several jobs or several parts of a job some distance apart. Obviously, you cannot be in two places at the same time. If someone is needed to make quick decisions during your absence, designate a man who is capable of making these decisions. This man should be capable of supervising the work in your absence, seeing that needed materials and supplies are on hand, and, in general, making the work go forward. Naturally, you should select a man for this job who can work without close supervision. Make him understand what you expect of him, and be specific concerning the limits of his authority. For example, you should make clear to him that the specs for the job must be followed unless they are changed by higher authority.

JOB INSPECTIONS

Periodic inspections are one important method of ensuring proper quality of work done under your supervision. Let your men know that their work is likely to be inspected. When you make an inspection let the man or men concerned know how well or how poorly they did the job. A man's work is not likely to improve if he is not told specifically wherein his work needs improvement; and a man who has done an excellent job will be motivated to continue this level of work if you let him know that good work is noted and appreciated.

Examples of work which you should carefully inspect are installations of switch boxes and bends in conduit. A switch box may be installed perfectly as far as the electrical aspects are concerned but be poorly installed with respect to neatness of appearance. For instance, if the switch box is not placed deeply enough in the wall, it will be impossible to make the plate which covers the switch flush with the wall. A protruding plate gives the finish a rough appearance.

The bends in conduit which run to panel boxes and junction boxes should be uniform. Bends which are not uniform give a poor appearance and the impression of sloppy work. Impress upon your men that neatness, as well as technical correctness, is important in electrical work.

It is essential, of course, that work which you inspect conform to the electrical code and specifications for the job. Make certain that the work is technically correct, and then inspect for neatness.

SHOP SUPERVISION

For most overseas assignments, you will have to set up the electrical shop. The equipment and materials needed for the shop will be determined by higher authority before you leave the United States. The shop will normally require a test switchboard, megger, grinder, hydraulic pipe bender, power threaders, and other portable equipment necessary for electrical work. Large equipment such as bench lathes and coil winders are not normally necessary in the electrical shop; this type of equipment, however, will generally be available in a separate battalion machine shop or in a shop on the base to which you are assigned. The layout of your shop will depend upon the amount of equipment and the space which is available. During time of war, when a battalion would take a complete set of electrical equipment for the deployment, you would need to consult standard drawings shown in Advanced Base Drawings, NavDocks P-140. These drawings recommend layouts for various types and sizes of electrical repair shops at advanced bases.

Repair Parts

The main function of the electrical shop is to keep all electrical equipment for the battalion or detachment in first class working order. You will need an adequate stock of repair parts to do the job. These parts range from attachment plugs for small drill motors to parts for welding machines. The shop will also need miscellaneous items, such as lamps for replacement purposes.

Have a reliable man survey all electrical tools and equipment in the battalion, and then see that there are parts available to repair each item. A quarter-inch drill that becomes inoperative because no repair part is available can cause as serious a delay as a larger piece of equipment which is out of commission.

A system of file cards will be necessary to keep track of the repair parts in stock. Place a man in charge of issuing parts and seeing that proper records are kept. When a part is used, it should be charged off on the card; when new parts are received, they should be added to the listing to show that they are on hand.

Work List

It is a good idea to make up a list showing the duties of each man assigned to the electrical shop. Such a list should show specifically the duties and responsibilities of each man and his assigned hours of work. Sometimes it will be necessary to work in shifts; advance notice to your men will enable them to plan their free time.

PASSING THE WORD

Passing the word is an important part of supervision. The battalion commanding officer, your company commander, and other higher authority frequently issue orders or directives which you should pass on to your men. You should be familiar with all instructions and notices that affect your work and the work of your men and make certain that they have this information.

Orders and directives from higher authority may pertain to a particular job, recreation, liberty, military requirements, or safety. If the information is the type that you can pass orally, you should consider the best time to pass the word on. Morning quarters and special musters are often suitable times.

You will need to put certain types of information into writing in the form of a written

directive. There is considerable personnel turnover in most units, and it takes a new man several weeks or months to learn about all policies. His task is even harder if there are no written directives to which he can refer. Safety requirements, local policies with respect to the use of Government material, tools and equipment, and local shop rules are examples of information which should normally be in written form.

SAFETY

As a senior petty officer, your responsibilities for safety are considerable. Never overlook the safety factor in making a decision or giving an order; remember also that safety attitudes cannot be separated from safety practices. Use every practical method to make your men safety conscious.

U.S. Navy Safety Precautions. OpNav 34P1, prescribes standard measures against the most common types of hazards which naval personnel are likely to encounter. One complete chapter discusses safety with respect to electricity and electronics equipment. You should become familiar with this publication. Remember, however, that the discussion in U.S. Navy Safety Precautions applies only to the most common hazards.

It is usually necessary to issue special precautions to cover local conditions and unusual circumstances. It is also necessary to keep a close watch to see that your men have the proper tools and clothing for each job on which they are working. There is a tendency for personnel to use clothing or tools that are handy, rather than going to some trouble to observe safety precautions. For instance, in splicing lead-covered cable, a man may find that no cotton gloves are handy when it comes time to wipe the joint; if a pair of leather-palmed gloves are handy, he may want to use them instead of the cotton ones. This man should be reminded that this is a dangerous practice; leather can transfer heat from the lead and cause a serious burn.

Other safety practices to follow during splicing include wearing goggles and high-top shoes and keeping sleeves rolled down.

SHOP SAFETY

There are numerous safety precautions that have particular application to shop work. See that your men follow them all. It is a good idea to list certain precautions which must be followed in the shop; safety posters may also be useful. Some important safety precautions for the shop follow.

See that men repairing electrical equipment at benches stand on a rubber mat or other approved insulating material.

Allow no electrical tools or equipment to leave the shop unless they have proper grounding facilities. In some localities, you may not have the three-wire grounding receptacles, which are required under safety regulations. If you are unable to get the three-wire receptacles, connect the third wire on the cord to a screw or bolt on a suitable ground.

Make certain that goggles are located near all bench tools which could cause an eye injury during use.

See that all shop machinery and equipment are kept free from oil, grease, carbon, dust, and dirt.

Allow no matches to be lighted or other open flames to be used in confined spaces containing combustible material.

Do not allow flammable liquids such as gasoline and benzene to be used as cleaning fluids on electrical equipment.

Use only rubber of insulating hose for blowing out equipment. Use no more than 50 pounds of pressure to avoid damage to insulation.

PAPERWORK

At the first class and chief levels your administrative duties will increase. With this increase will come additional paperwork-records, reports, instructions, and so forth. We have already mentioned the duties connected with scheduling of work, making and studying bills of material, and preparing directives.

It is absolutely essential for you to be systematic in keeping files and records. There may be a temptation to keep your administrative duties and responsibilities in your head; as work requests, reports, and publications pile up, however, you will find it necessary to arrange them so that each one is readily available when needed. Tossing papers on your desk or filing them carelessly in a drawer will eventually cause your records to become hopelessly fouled up. Try to keep your files in such a manner that the man who steps into your job can understand the status of all job assignments and work requests.

SUPPLY MATTERS

Most material which you require to do your job is issued after you have filled out the proper supply form. At some activities you will be authorized to sign this form; at others, it will have to be signed by an officer. Keep accurate records of what you order and when you receive it.

A record of tools and other equipment permanently assigned to you is kept on stock custody cards; you will have to sign for this equipment. Keep track of all items permanently assigned to your shop. Have anyone removing these items from the shop sign for them. Once a year, and whenever your company commander is relieved, you will have to take physical inventory of equipment assigned to you.

You may also have to fill out forms when a piece of equipment is to be SURVEYED. When a piece of equipment needs to be disposed of because of wear, irreparable damage, or because it is obsolete, a record must be made showing the condition of the material, the cause of the condition, the responsibility therefor, and the recommendation for disposition. An officer or a survey board must approve the request for survey. Your part in this procedure is to initiate the survey request. The request should contain complete information about the piece of equipment, why it should be surveyed where it is located, and other pertinent data.

WORK REPORTS

As mentioned earlier, you will need to put in a daily work report for projects in the field showing the number of hours that each man put in on a particular job. Figure 9-3 is a typical daily work report. The report lists the name of each man in the work crew and indicates the number of hours he spent on particular jobs. The report may indicate time lost through sickness, authorized absence, bad weather or other causes.

SKETCHES

One type of paperwork that can save you time and trouble is the handmade sketch. When telling a man or group of men about some particular job or how to do a particular job, you will often find it useful to make a sketch of the job. If you turn the sketch over to the man, he can use it as a guide without having to rely completely on his memory. A sketch is also useful in helping a man understand points which are hard to explain orally. Encourage your men to ask questions after seeing a sketch to be certain that they understand exactly what you have in mind.

CHAPTER 10

DEFENSIVE COMBAT

In peacetime, Construction Battalions may be deployed in outlying areas where unexpected attacks could occur. Seabees must be prepared to carry out construction missions but it is equally important to be prepared for combat. In the event that a Construction Battalion is involved in a combat situation every second counts; every unit must be able to deliver its full combat potential immediately.

Under wartime conditions, Construction Battalions often work in combat areas. In these areas, the battalion is subject to infiltration, and raids. Battalions are responsible for their own security; they must defend their own job site and camp areas. In addition, they may be called upon to contribute to the defense of the base to which assigned and carry out other combat operations as required. Although normally assigned to construction missions, in an emergency, Construction Battalions may be required to reinforce an amphibious operation or to provide infantry support in a combat area.

From the foregoing discussion it is obvious that a Construction Battalion must be prepared for combat both in peacetime and in wartime. Every man in a battalion, therefore, has both a construction assignment and a combat assignment. The battalion organization for construction and for combat exists simultaneously. Thus a battalion can work, fight, or work and fight with no basic change in its organization.

BASIC COMBAT ORGANIZATION

The construction/combat organization for Construction Battalions is outlined in MOBILE CONSTRUCTION BATTALION ADMINISTRATION, NavDocks P-315, dated November 1959. A construction/combat organization is given both for a Construction Battalion (large) (functional component P-1) and for a mobile construction battalion (functional component P-25). The Construction Battalion (large) is sometimes called a full-strength battalion. This terminology resulted from the fact that the MCB personnel allowance is about one-half the allowance of a Construction Battalion (large). Correct terminology is now Construction Battalion (large) (or simply P-1) and Mobile Construction Battalion (or MCB or P-25).

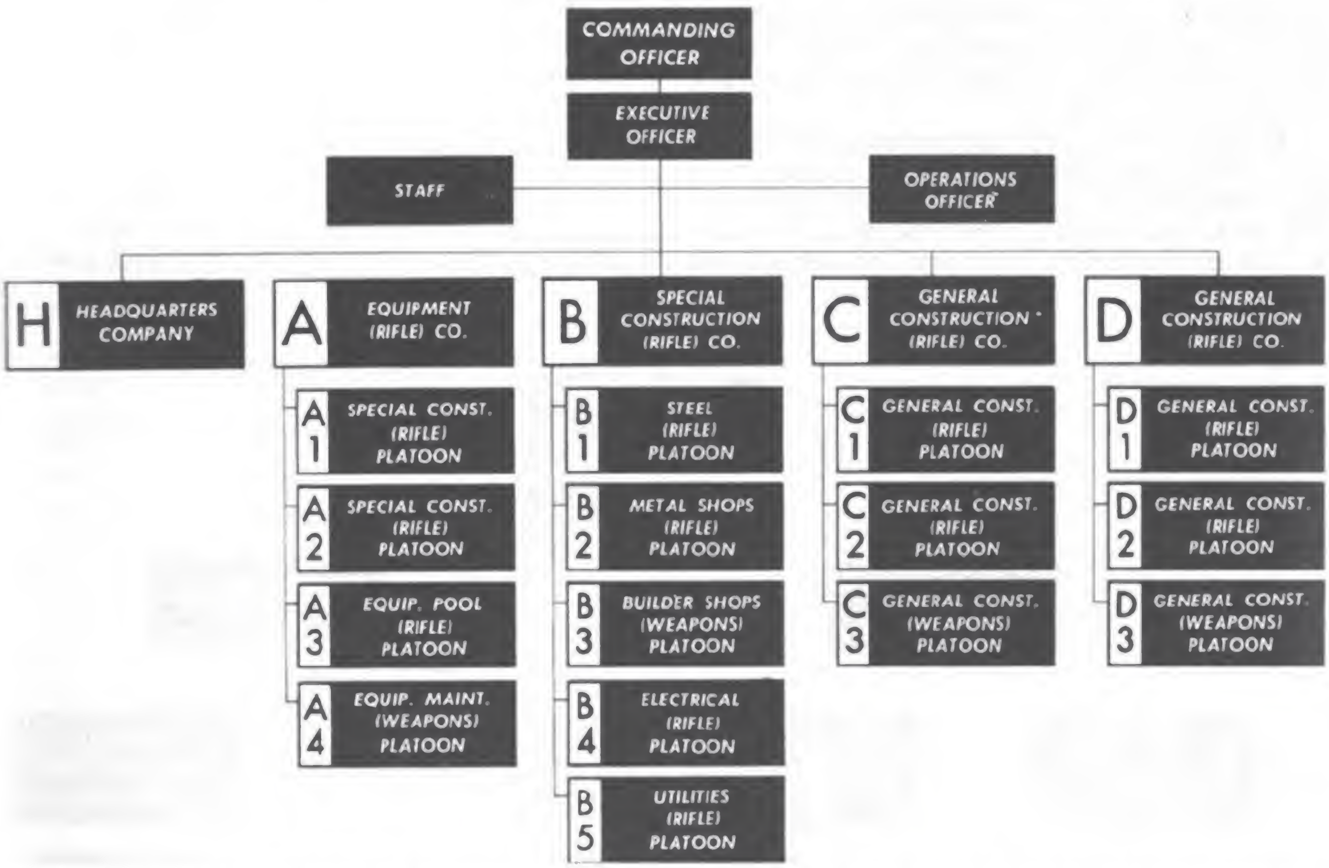
In most cases a battalion is organized to the platoon level as shown in NavDocks P-315. (NOTE: NavDocks P-315 of November 1959 is being revised; the basic concept of construction/combat organization will remain the same but details of organization will vary.) A battalion may organize the subdivisions of a platoon (squads and fire teams) to meet its particular needs. Each subdivision of the platoon, however, must be organized as a construction/combat squad made up of work crew/fireteams. As far as possible, the make up of a squad or a fire team should follow the Landing Party Manual—that is, four men to a fire team and three fire teams to a squad. The military duties of a CE1 or a CEC vary with the strength of a battalion and the personnel available. In general, a CE1 is expected to lead a fire team, and a CEC is expected to be a squad leader. In the absence of an officer to serve as a platoon leader, however, a CEC may have to lead a platoon. Similarly, a CE1 may have to serve as squad leader.

FULL-STRENGTH BATTALION

The basic construction combat organization of a Construction Battalion (large) is shown in figure 10-1. As you will note, there are four rifle companies and a Headquarters Company. Each rifle company is divided into three or more rifle platoons, plus weapons platoon. (The construction mission of each company and platoon is also shown in figure 10-1.)

Headquarters (or H) company consists mainly of personnel in the administrative and supply ratings—Yeoman and Storekeeper, for example. There are, however, some Seabee ratings in H Company, particularly men in the Engineering Aid (formerly Surveyor or Draftsman) rating. Men in H company perform combat duties related to intelligence and operations functions.

Each lettered company (A, B, C and D) acts as a rifle company in defensive combat. The



NOTE: THE OPERATIONS OFFICER FUNCTIONS IN A STAFF CAPACITY DURING COMBAT ONLY. IN CONSTRUCTION OPERATIONS, COMMANDERS OF COMPANIES A, B, C, AND D TAKE ORDERS DIRECTLY FROM HIM.

2.223

Figure 10-1.—The construction/combat organization for construction battalion (large).

numbered platoons in each company (such as B1, B2, B3, B4, and B5 always retain their letter number designations for combat purposes. Thus the platoon to which Construction Electricians are assigned is known as B4. In a Construction Battalion (large), this platoon, B1, B2, and B5, are rifle platoons. Men in platoons B1, B2, B4, (CE's), and B5 serve in rifle squads. A typical rifle squad consists of three fire teams (but may have more or less). A fire team normally consists of four men—one automatic rifleman and three riflemen; a fire team, however, may have only three men. If a squad has only one automatic rifle, a typical fire team (other than the one with the automatic rifle) will consist of one rifleman with a grenade launcher and three ordinary riflemen.

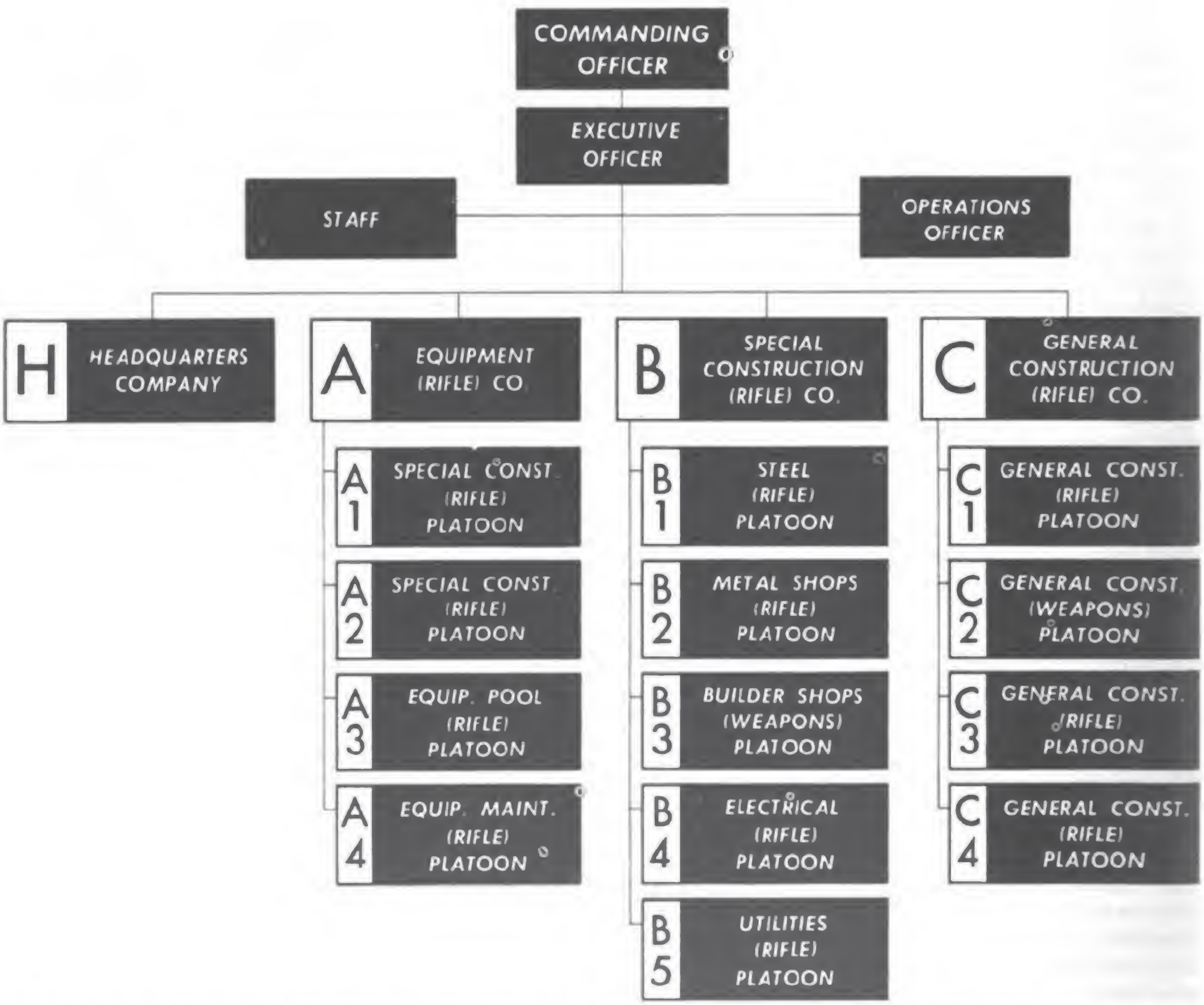
In a Construction Battalion (large) platoon B3 is the automatic weapons platoon. The type of automatic weapons provided will depend upon the location and the type of combat expected. Typically, the platoon will have three .30 caliber machine guns and two .50 caliber machine guns. Under certain conditions this platoon might be assigned a 3.5 inch rocket launcher or other heavy weapons. A typical machine gun crew consists of four men: a gunner, assistant gunner, an ammunition carrier, and a rifleman. The assistant gunner and ammunition carrier are armed with rifles. Men in the weapons platoons who are not in the machine gun crew (or a rocket launcher crew) act as riflemen.

MOBILE CONSTRUCTION BATTALION

In peacetime, Construction Battalions (large) normally do not operate; MCB's carry out most

assignments of the Naval Construction Forces. An MCB may also operate during wartime. The peacetime strength of an MCB (P-25) varies between 225 and 550 men.

Figure 10-2 shows the typical organization of an MCB. You will note that this organization is essentially the same as for a large battalion. The main difference is that the strength of H, A, and B companies is reduced. D company is deactivated entirely and C company may have four platoons instead of three. On board strength of an MCB may vary considerably; the number of personnel is tailored to meet operating conditions in the area where the battalion is deployed. Nevertheless, the organization pattern remains basically the same. It is expected that when a man is transferred from one battalion to another he can quickly grasp his functions in



NOTE: THE OPERATIONS OFFICER FUNCTIONS IN A STAFF CAPACITY DURING COMBAT ONLY. IN CONSTRUCTION OPERATIONS, COMMANDERS OF THE EQUIPMENT AND CONSTRUCTION COMPANIES TAKE ORDERS DIRECTLY FROM HIM.

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Figure 10-2.—Construction/combat organization for Mobile Construction Battalion (MCB).

the new battalion without the need for extensive orientation. Similarly, if a man is transferred from an MCB to a Construction Battalion large (or vice versa), there is virtually no problem in learning how he fits into the new organization.

COMBAT OPERATIONS

In combat, the battalion, companies, squads, and fire teams operate on the principles given for the individual and the group in the Landing Party Manual, 1960 OpNav P34-03. Every officer and man must understand his combat responsibilities, as well as his construction duties.

Although the combat principles spelled out in the Landing Party Manual apply to Construction Battalions (large) and to MCB's the recommended organization does NOT apply; the personnel strength of a naval infantry battalion does not match the strength of a Construction Battalion either large or mobile. For example, a rifle platoon of an infantry battalion has one officer (a lieutenant (jg) or ensign) and 44 enlisted men. In a Construction Battalion (large) the strength of a rifle platoon varies from 52 men to 84 men, with one warrant officer. Furthermore, the second in command of a rifle platoon of an infantry battalion is normally a petty officer second class; the second in command of a rifle platoon of a Construction Battalion (large) is normally a chief petty officer. In some cases a CPO may act as platoon leader. He may also be a fire team leader and squad leader. Thus, the range of duties that a petty officer may be assigned varies more in a Construction Battalion than in an infantry battalion.

One method of keeping standard rifle platoons (that is, three squads to a platoon) is to assign extra men to platoon headquarters. The alternative is to have more squads than the three recommended in the Landing Party Manual. Two machine guns (or sometimes three) make up one section. Under normal conditions a section is the fire unit. This means that two guns are generally assigned the same mission. A section may be split under any of the following conditions: (1) when the front is overly extended, (2) when the field of fire is poor, or (3) when guns need to be placed in depth (as with reserve units).

Machine guns employed through the defensive position normally have one or more of the following missions:

1. To serve as the final protective line
2. To serve in close support of the main line of resistance
3. To provide depth to the defensive position
4. To protect the flanks and rear
5. To support counterattacks

The main consideration in the selection of firing positions for machine gun sections is the accomplishment of the assigned mission. Other factors, however, must also be considered. Cover and concealment of the gun and crew are essential if the gun is to remain in action; automatic weapons such as machine guns are almost always the main target of enemy infantry. Intelligent use of natural terrain will reduce labor and time necessary to construct gun emplacements.

In selecting machine gun positions consideration should be given to the routes of ammunition supply which will provide maximum protection. When the original supply of ammunition is exhausted, a route by which additional ammunition can be brought up is essential.

In most cases it is necessary to clear a field of fire for a machine gun. Only enough foliage to allow an unobstructed field of fire should be cut; the clearing of all foliage makes it easier for the enemy to locate the gun position.

When a section is emplaced, the two guns should be at least 30 yards apart. Separating the guns makes it more difficult for the enemy to score hits with mortar or artillery fire.

If the company captures an enemy position, immediate steps must be taken to hold it. The principal means of holding a captured position is a quickly developed machine gun fire plan. As soon as the position is taken from the enemy, machine guns must be moved up for protection. The entire front and flanks of the company should be covered by assigning overlapping sections of fire to each machine gun section. The positions for the machine guns are selected by the platoon commander in accordance with instructions of the company commander.

TACTICS FOR RIFLE UNITS

During combat, fire teams, squads, platoons, companies, and the battalion operate according to the general principles stated in the Landing Party Manual. The battalion commanding officer is responsible for battalion tactics during combat if the entire battalion is engaged. Company commanders are responsible for company tactics and platoon leaders for platoon tactics. As mentioned before, a chief may occasionally have to serve as platoon leader. and therefore platoon

tactics are discussed in this chapter. Normally chiefs serve as squad leaders with petty officers first class serving as leaders of fire teams.

Tactics for fire teams, squads, and platoons are all discussed in this chapter.

Fire Teams

A fire team is the smallest combat unit of a rifle platoon. It consists of a leader, an automatic rifleman, as assistant automatic rifleman, and a rifleman. A fire team sometimes consists of a leader and three riflemen, one of whom has a grenade launcher. The fire team leader is usually a petty officer first class but may be a second class or chief. The remainder of the team may be petty officers second class, third class, or constructionmen. Every member of a fire team must understand the duties of every other member and must be prepared to assume any position on the team.

The fire team leader is responsible for the employment of his team during combat, for fire discipline and fire control of the team, and for the condition of the team's weapons and equipment. (Fire discipline and control are discussed later.)

A fire team leader takes his orders from the squad leader. In the absence of the squad leader, the senior fire team leader takes command of the squad. During combat, the fire team leader takes position where he can best carry out the orders of the squad leader while observing and controlling his fire team. If there is an automatic rifle with the team, the fire team leader locates himself near enough to this weapon to exercise effective control over it. Besides his primary function, the fire team leader serves as rifleman.

CHARACTERISTICS OF FIRE TEAM FORMATIONS.—Standard formations for the deployment of fire teams are the column, wedge, skirmishers right/left, and echelon right/left. These formations are shown in figure 10-3.

The COLUMN formation permits rapid, well-controlled movement. It is vulnerable to enemy fire from the front, however, and should be changed when maximum fire power is needed to the front.

The WEDGE formation permits good control and use of almost all fire to the front. It provides all around protection and readiness for action in any direction.

The SKIRMISHER formation allows use of maximum fire power to the front. It is best employed in the assault on an enemy position.

The ECHELON formation is similar to the skirmisher formation except that one flank is drawn back from the front, permitting fire to the front or flank.

USE OF FIRE TEAM FORMATIONS.—Initial formations are usually ordered by the platoon leader for the squads, and by the squad leaders for the fire teams. Thereafter, each leader will determine his unit's formation after giving consideration to the mission, the terrain, and the location and strength of the enemy. Thus, a fire team leader may change the formation of his unit to reduce casualties from hostile fire, to present a less vulnerable target, or to negotiate difficult or exposed terrain. Although there is a fire team formation which is more or less appropriate to each squad formation, a squad may contain fire teams which are in a variety of formations; these formations may be shifted frequently to take advantage of circumstances. In any event, the tactical disposition of the fire teams in a squad must never be one in which one team will mask the fire of another.

It is not essential that exact distances and intervals be maintained between fire teams, or between individuals in a team, as long as good control is maintained. Sight or voice contact should be maintained within the fire team, and also, when practicable, between fire team leaders and squad leaders.

All movements incidental to shifting formations should be by the shortest practicable routes. Backward or lateral movements must be avoided whenever possible. During any movement, the greatest possible advantage must be taken of available cover and concealment.

Squads

A squad consists of the squad leader and two or three fire teams.

The squad leader carries out the orders issued by the platoon leader. He is responsible to the platoon leader for the control and conduct of his squad at all times, and he is also responsible for the fire discipline, fire control, and maneuver of his squad. He takes position where he can best carry out the orders of the platoon leader and observes and controls the squad. The squad leader participates in the firing only in critical situations.

CHARACTERISTICS OF SQUAD FORMATIONS.—Standard formations for the deployment

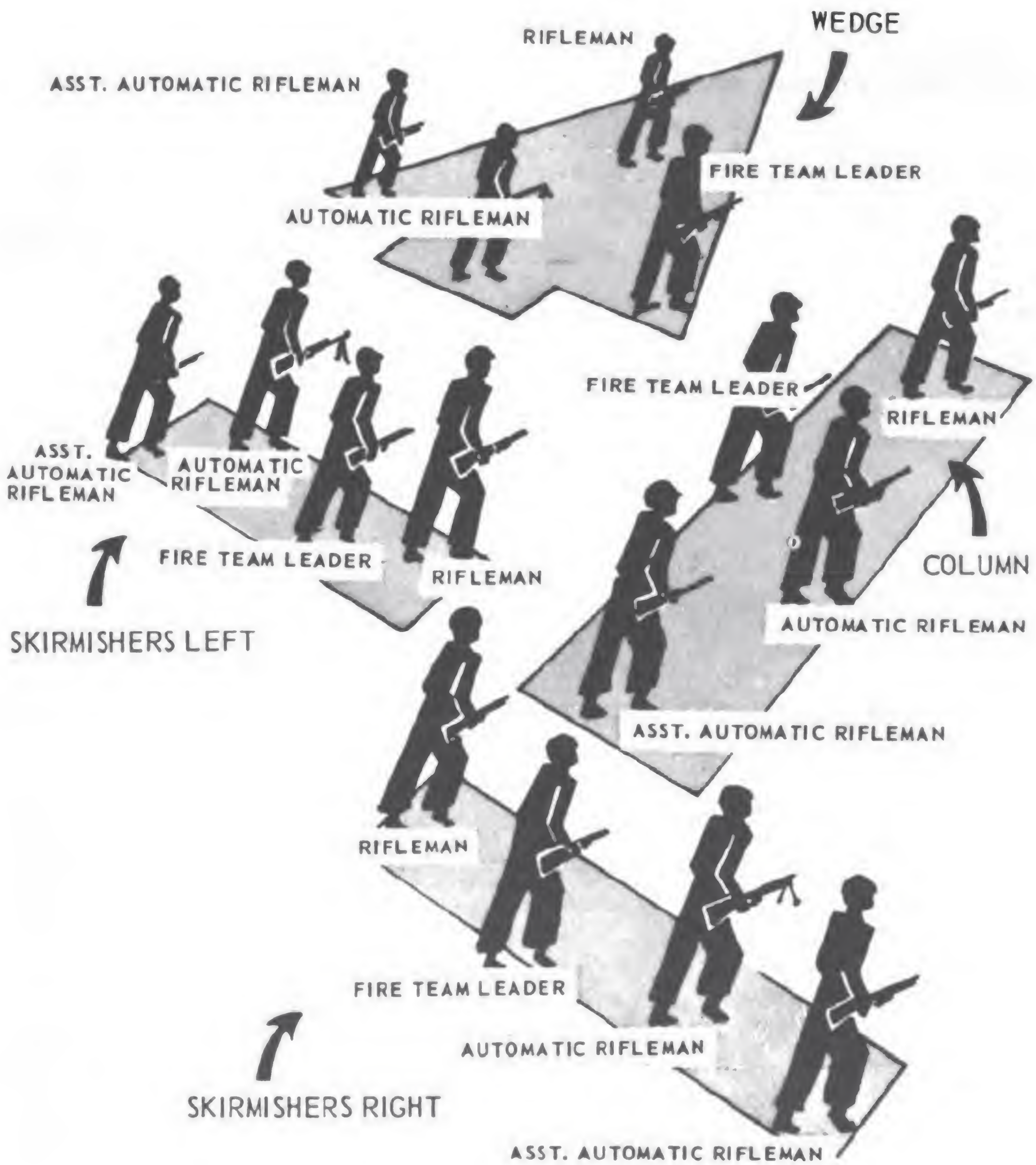

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Figure 10-3.—Basic formations of the fire team.

of the rifle squads are: squad column (column of fire teams) (fig. 10-4); squad wedge (one fire team forward, two fire teams back) (fig. 10-5.); squad vee (two fire teams forward, one fire team back) (fig. 10-6); squad line (line of fire teams) (fig. 10-7); squad echelon right/left, (fig. 10-8).

In squad column the fire teams are arranged in succession one behind another. This formation is vulnerable to fire from the front. However, it is easily controlled and maneuvered.

The squad wedge and squad vee formations provide security to both front and flanks, favor

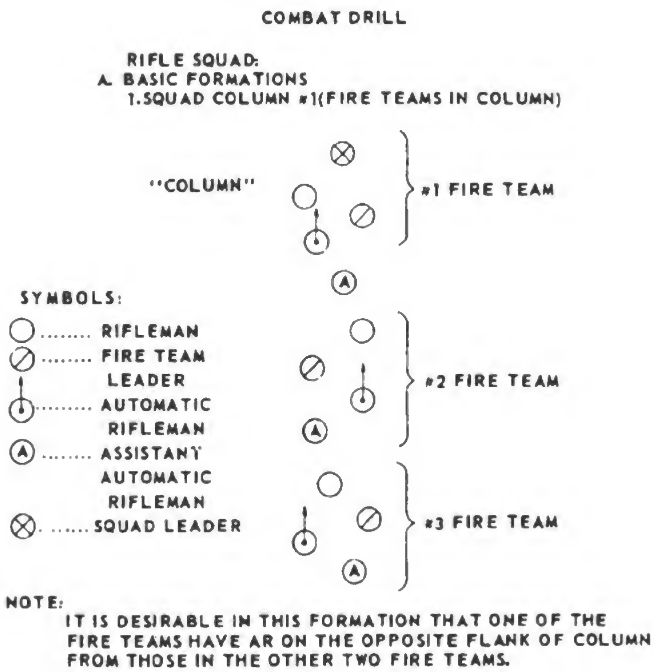

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Figure 10-4.—Squad column, fire teams in column.

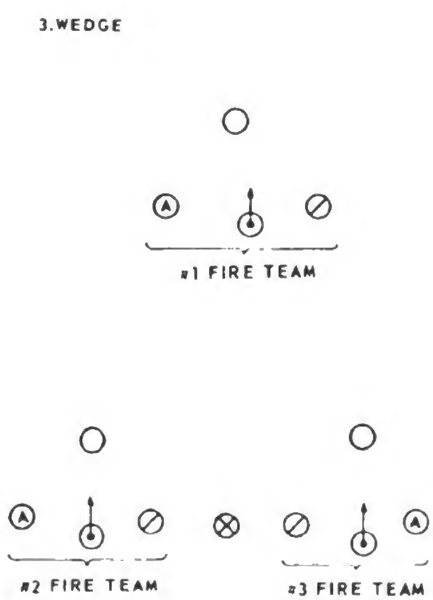

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Figure 10-5.—Squad wedge, fire teams in wedge.

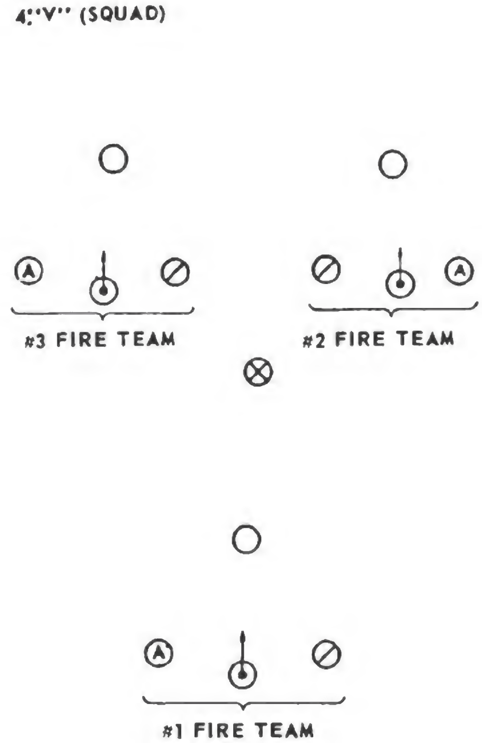

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Figure 10-6.—Squad vee, fire teams in wedge.

maneuver and control, and also provide flexibility in meeting new tactical situations. The factors that usually determine which of these formations is to be employed are the terrain, the frontage which the squad is to cover, and the proximity and actions of the enemy.

The squad line formation places all three teams abreast of one another on a line. It permits the squad leader to develop the maximum fire power to the front in the shortest time. It is suitable for rapidly crossing an area exposed to hostile long range machine gun fire from the front or artillery fire which cannot be avoided.

The squad echelon right formation may be used to protect an exposed right flank; it permits maximum fire to be delivered promptly toward that flank or the right front. The squad echelon left formation accomplishes the same purpose for the left front and left flank. The standard combat formations for the squad (or for the fire team) should be based on the tactical situation.

SQUAD DEFENSIVE ROLE.—A rifle squad normally defends an assigned portion of an area

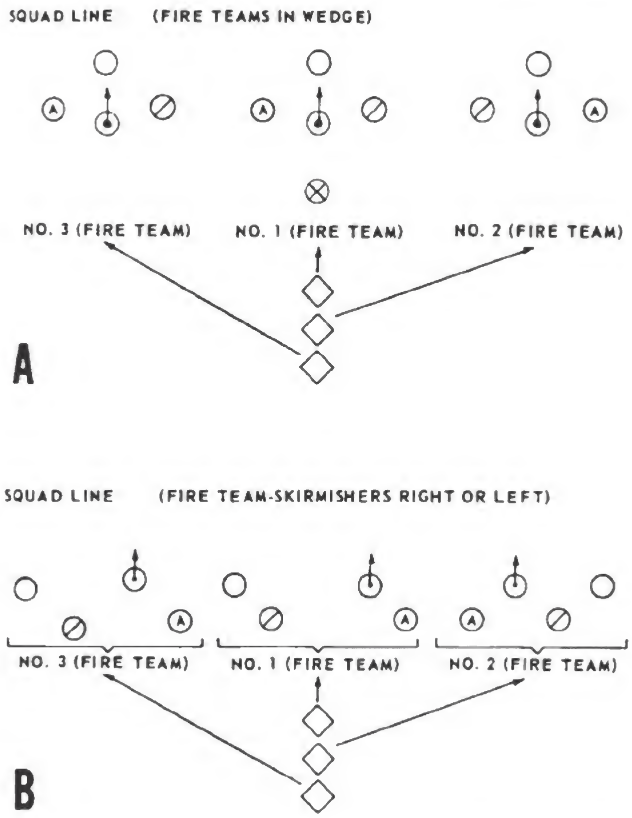


Figure 10-7.—A. Squad line, fire teams in wedge; B. Squad line, fire teams skirmishers right and left. 2.230

defended by a platoon. On rare occasions a squad may be assigned to a location separate from the platoon—for example, a combat outpost (discussed later).

The rifle squad's role in the defense depends upon the mission to which assigned. This mission may be as part of the holding garrison, as a security element, or as a part of the reserves. As part of the holding garrison, the squad occupies a defense area on the main line of resistance (an imaginary line along the forward edge of the battle position designed to coordinate the fires of all units and supporting weapons). The squad position is normally 50 to 100 yards wide and up to 50 yards deep. The squad may tie in with adjacent squads, or gaps may exist between positions. This depends on the nature of the terrain, the size of the platoon defense area, and other factors. When gaps between squads exist, they must be covered by fire. The platoon leader assigns sectors of fire to his squads, each of which overlaps sectors of adjacent squads.

A squad serving as a security element is located forward of the main line of resistance. The squad's usual mission in this capacity is to gain information of the enemy and to delay his advance. The squad leader notifies the platoon of the enemy's strength, actions, direction of advance, and weapons and equipment. On order, the squad withdraws along a predetermined route to the line of main resistance.

If the squad is to serve as part of the reserves, it is placed to the rear of the front-line units. A reserve squad may be ordered to defend a position from which to limit enemy penetration of the main line of resistance; or the squad may be ordered to counterattack as part of a larger force.

LEADING THE SQUAD.—After the platoon leader gives orders for defense of the area, the squad leader should make a reconnaissance of the area assigned his squad and assign each fire team to a particular location. As a squad leader, select an area for yourself where you can best control the squad. Have the men dig foxholes or camouflage themselves as necessary.

After combat activities begin, maintain personal contact with other squad leaders and the platoon leader, to the extent possible. Through this contact, you can coordinate the fire of your squad with the fire of adjacent squads. If there are supporting weapons such as machine guns, rockets, or recoilless rifles in the area, be sure that these weapons receive adequate protection. Also see that flanks and the rear are guarded. As a squad leader you may issue orders directly to the squad members or only to the fire team leaders, depending upon time available and circumstances. Orient your men on the map (if one is available) and on the ground by pointing out the direction of north; also indicate the fire direction from which the enemy attack is expected. Ensure that your squad understands its mission and its fire sector. Order the squad to shift its fire if an adjacent area is overrun, and move the squad as necessary to protect the flanks.

Platoons

The leader of a rifle platoon is normally a lieutenant (jg), an ensign, or a warrant officer. Sometimes, however, a chief must act as platoon leader.

In a naval landing party a rifle platoon normally consists of three rifle squads, platoon

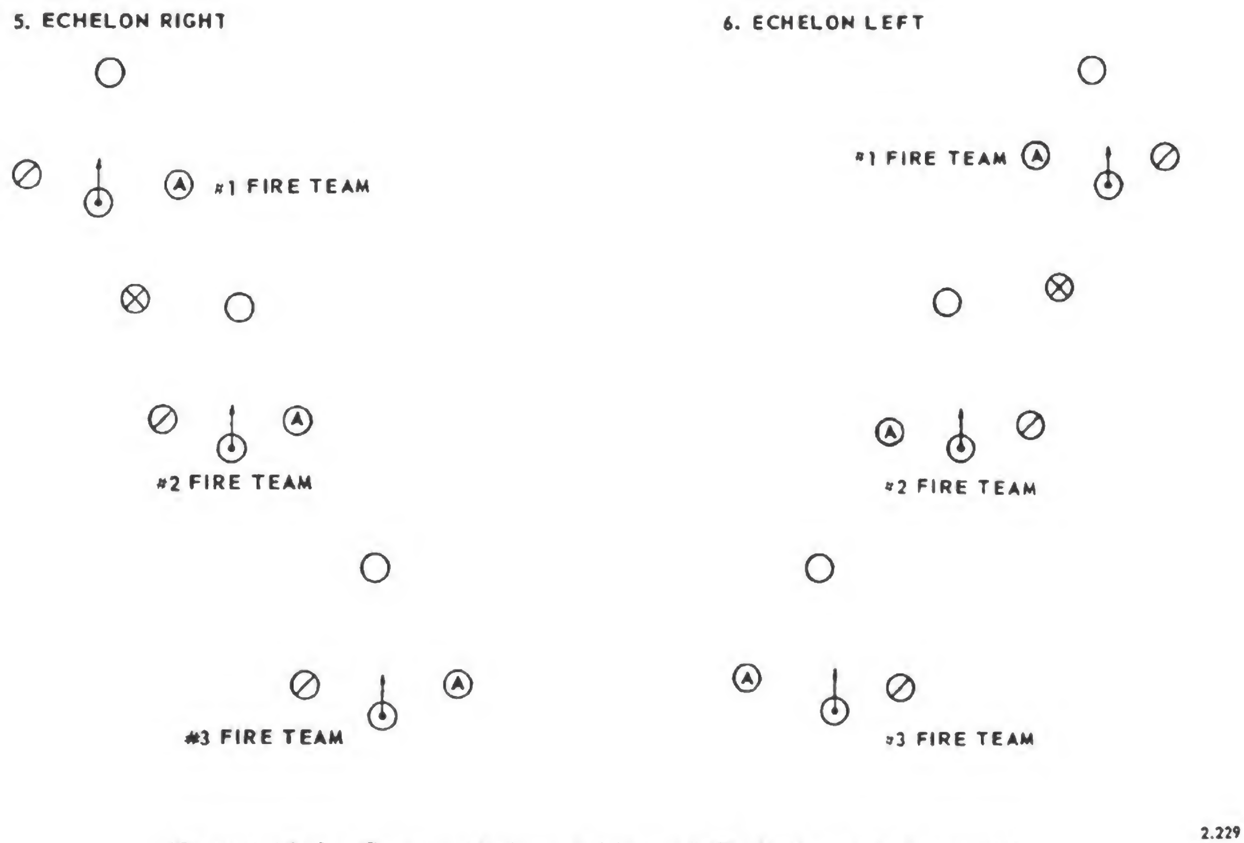


Figure 10-8.—Squad echelon right and left, fire teams in wedge.

headquarters, and a platoon leader. As stated before, the organization of a platoon in an MCB varies according to the needs of the battalion and the personnel available. Since there are more men in a typical MCB platoon than in a landing party platoon, there may be four, instead of three, squads in an MCB platoon. Platoon headquarters consists of riflemen and messengers.

PLATOON FORMATIONS.—Standard formations for the deployment of a platoon are similar to those for the squad; they are the platoon column, vee, line, wedge, and echelon right/left.

The PLATOON COLUMN is generally used for approaching an enemy position that is believed to be directly to the front but that has not yet been located. It is normally the best formation for movement in woods, smoke, fog, at night, and along trails. The platoon column is easy to control and is flexible; it provides some all-around protection and permits immediate action toward the flank.

The PLATOON VEE is used when the enemy is believed to be directly to the front and his approximate strength and location are known. It provides security to the front and both flanks and favors maneuver and control.

The PLATOON LINE is used when the location and strength of the enemy are known. It lets the platoon deliver the greatest fire power to the front in the shortest time. It is very useful during the assault phase of an attack or to cross an area exposed to mortar, artillery, or long-range machine gun fire.

The PLATOON WEDGE is used when little is known of the enemy strength and disposition or when the platoon is acting alone. It provides a high degree of flexibility, gives all-around protection, and is easy to control.

The PLATOON ECHELON RIGHT OR LEFT is used to protect an open or exposed flank. It permits heavy fire to the front and in the direction of the echelon.

LEADING THE PLATOON.—After receiving the order from the company commander, it will be up to the platoon leader to do the following:

1. Select a vantage point. Accompanied by the platoon guide and messengers (runners), he

should move to his platoon defense area and select a position from which he can view as much as possible of the platoon defense area and area forward of the main line of resistance.

2. Arrange to meet subordinate leaders and have platoon move forward. Assuming the platoon has remained in the company assembly area while the company defense order was given, the platoon commander should send a messenger to bring the squad leaders to the platoon vantage point. This messenger may also tell the platoon chief to move the platoon to the platoon assembly area designated by the platoon leader within or just behind the platoon defense area.

3. Plan and make a reconnaissance. The platoon leader should plan and make his reconnaissance while the platoon and the squad leaders are moving forward. If the enemy situation allows, he should begin on the enemy side of the main line of resistance in order to see his position, and routes of approach to it, from the enemy viewpoint. He should then walk along the main line of resistance and examine the rear of the platoon defense area. During his reconnaissance, he should select positions for his squads. He should also select an observation post. He should decide the tactical organization, fire plan, and how the platoon will organize the ground.

4. Contact adjacent and supporting unit leaders. He should make these contacts to coordinate his fire with theirs. Meetings between platoon leaders should take place at the juncture of platoon defense areas. Although company commanders coordinate fires between companies, platoon leaders on the company flank should check with adjacent flank platoon leaders to ensure fires have been properly coordinated platoon-wise.

5. Orient subordinate leaders. After completing the reconnaissance and meeting other platoon leaders, the platoon leader should return to his vantage point to orient his subordinate leaders. The squad leaders should be shown the expected direction of enemy attack, the limits of the platoon front, the location of adjacent and supporting platoons, locations and missions of supporting weapons within the platoon area, and the general position to be occupied by the squads.

6. Issue the defense order. The platoon leader should then issue the orders he received from the company commander: They should be complete and practical. The more of the situation the men know, the better the platoon's chances of success.

7. Supervise the execution of the order. After issuing the order the platoon leader must supervise its execution. He must point out to each squad leader his sector of fire, and the principal direction of fire for each automatic rifle. He must ensure that his fire plan is being properly prepared and that the avenues of approach not covered by machine gun grazing fire are well covered by automatic rifle fire (grazing fire is fire in which the trajectory is no higher than the height of a man standing). He must also enforce proper camouflage and noise discipline. The supervisory duties of the platoon leader never cease; he must continuously improve ground organization as long as the position is occupied.

PLATOON DEFENSIVE ORGANIZATION.—The rifle platoon will usually best accomplish its mission with three squads abreast, facing the expected direction of attack. This enables the platoon to place its fire power in front of the main line of resistance. Squads are not kept in reserve for the missions normally assigned a reserve unit. These missions are more effectively accomplished by units with more combat power than a squad. The platoon with three squads abreast is able to cover its front and the intervals on its flanks, and also mutually support adjacent platoons. When a narrow gap exists between platoons, it is possible to place the squads abreast without echeloning the flank squads rearward. A wide gap necessitates bending back the flank squads in order to gain mutual support between platoons. Each squad is assigned a sector of fire which overlaps that of the adjacent squads, including those of adjacent platoons. When two squads can cover the platoon front by fire and a suitable depth position exists in the platoon defense area, one squad may be placed in the depth position. The depth squad must, however, be able to bring its fire to bear forward of the main line of resistance.

SUPPLEMENTARY POSITIONS.—The rifle platoon must be able to defend its area against attack from any direction. Squad supplementary positions which allow the squad to fire to the flanks and rear are therefore prepared. These positions should be located as close to the primary position as the terrain permits; a good field of fire is essential. A squad on a forward slope might have its supplementary position just below the crest of the hill. The depth of a platoon area is determined by these supplementary positions. It is normally 200 yards or less. In open, flat terrain riflemen can shift their fire to the rear without changing position, thereby lessening

the depth of the defense. When supplementary positions are necessary, it is not anticipated that men can be readily shifted from one position to the other during a fire fight; the move would be overly dangerous. Adjustments should be made only when conditions permit and the situation dictates a change. Natural cover, drainage ditches and other covered routes should be used in moving to supplementary positions. If time permits, communication trenches may be prepared between positions.

TECHNIQUE OF FIRE

The technique of fire is the application and control of the combined fire unit. A rifle fire unit is a group of riflemen or automatic riflemen whose fire is under the immediate and effective control of a leader. A machine gun fire unit is a machine gun section (normally two guns) under the immediate control of a leader.

There are many aspects of the techniques of fire, including characteristics of fire, classes of fire, range estimations, fire discipline, fire control, fire distributions, and fire commands among others. In a training course it is not possible to discuss all of these fully. The Landing Party Manual contains a full discussion on all of these, as well as related topics.

RANGE ESTIMATION

In battle, ranges are seldom known in advance of actual combat. In order to bring effective fire on the enemy, men must be trained to estimate ranges quickly and accurately. Estimations are made either by eye or by observation of fire.

Estimation by the eye is the usual method of estimating range. It is accomplished by mentally applying a unit of measure to the distance to the target; the normal unit of measure is 100 yards. This method is difficult to apply to distances over 500 yards; for greater distances, the best procedure is to select a point halfway to the target and to apply the 100-yard unit. The result is then doubled.

It may also be possible to make eye estimations by mentally composing an arc between the target and a nearby object to the right or left of the target and estimating the distance to the object. This distance is considered the range to the target. This method is useful when much of the ground between the observer and the target is hidden.

It is also sometimes possible to estimate the range by the appearance of objects near the target.

Accurate estimation of ranges by eye requires considerable practice over all types of terrain and under all conditions of visibility. The use of ranges with known distances and with markers every 100 yards is recommended for training purposes.

FIRE DISCIPLINE

Fire discipline is the state of order, coolness, efficiency, and obedience existing among troops in a fire fight. It implies the careful observance of instruction in the use of the weapons in combat and execution of the exact orders of the leader. Fire discipline is necessary for proper control by leaders. The effectiveness of collective fire depends upon control by the leaders.

Fire discipline is maintained by unit leaders. In a platoon the responsibility rests with the platoon commander, assisted by the squad and fire team leaders.

Fire discipline in the squad is the responsibility of the squad leader. There is a tendency for untrained machine gunners and riflemen to open fire at night noises and other imaginary targets; this gives away positions and wastes ammunition. The squad leader must train his men in proper fire discipline.

FIRE CONTROL

Fire control includes all operations connected with the preparation and actual application of fire to a target. It implies the ability of the leader to have his unit open fire at the instant he desires, adjust the fire of weapons upon the target, shift the fire from one target to another, regulate the rate of fire, and cease firing at will. Lack of proper fire control results in loss of surprise effect, premature disclosure of position, misapplication of fire on unimportant targets, and waste of ammunition. Discipline and correct training are essential for adequate fire control.

The platoon commander's order to his squad leaders may do any of the following: (1) assign a mission to the squad, (2) give the firing position area each squad will occupy and the targets it will engage, or (3) designate the sector of fire each squad will cover.

The squad leader's order prescribes the location for each weapon and the targets to be engaged or sector of fire to be covered.

In the absence of orders from higher authority, fire is opened, lifted, or shifted by platoon or squad leaders. They also regulate the rate of fire.

FIRE DISTRIBUTION

To be effective, fire must be distributed over the entire target. Improper distribution results in gaps and may allow part of the enemy to escape, to advance, or to use his weapons without effective opposition.

Fire from a rifle unit is either CONCENTRATED or DISTRIBUTED. CONCENTRATED fire is directed at a single point—for example, an enemy machine gun or automatic rifle.

DISTRIBUTED fire is distributed in width to keep all parts of the target under effective fire. Each rifleman fires his first shot at that portion of the target that corresponds roughly to his own position in the squad. Thereafter, he distributes his shots a few yards to the right and to the left of his first shot.

The automatic rifleman normally fires at the entire squad target in short bursts. All squad members should fire upon positions most likely to contain an enemy—for instance, bushes, stumps, rocks, and patches of long grass.

A machine gun section (two guns) normally fires at the same target. This ensures continuous fire in case one gun is put out of action, provides a greater volume of fire on the target, and reduces the time required to cover the target.

FIRE COMMANDS

When the leader of a fire unit (fire team, platoon, or machine gun section) decides to fire on a target, he gives instruction to his men in the form of a FIRE COMMAND. For machine guns, a fire command has four elements: ALERT, TARGET DESIGNATION, METHOD OF FIRE, and the COMMAND TO OPEN FIRE.

The ALERT designates the gun crew that is to fire and alerts them to their fire mission. For example, FIRST SECTION, MOVING TARGET (or stationary targets, vehicles, or the like).

The TARGET DESIGNATION includes the direction of fire (such as FRONT) the target description (such as COLUMN OF TROOPS), and the range (usually in yards—for example, FIVE FIVE ZERO).

The METHOD OF FIRE designates the manner in which the target is to be engaged (for example, whether both guns will be trained on the same target or adjacent targets) and the rate of fire (rapid, medium, or slow).

The COMMAND TO OPEN FIRE may be COMMENCE FIRING or simply FIRE. If the leader wants to bring about a large volume of surprise fire, his command may be COMMENCE FIRING ON MY COMMAND. When all gunners have located the target, he then gives the order to fire.

There are six basic elements in a fire command for riflemen and automatic riflemen: ALERT, DIRECTION, TARGET DESCRIPTION, RANGE, TARGET ASSIGNMENT, and FIRE CONTROL.

The alert brings the unit to a state of readiness to receive further information—for example, SQUAD (or FIRE TEAM NUMBER ONE). If all men in the unit are not to fire, the leader may designate men by names after giving the SQUAD or FIRE TEAM alert.

The DIRECTION element tells the riflemen which way to look to see the target—for instance, RIGHT FRONT. The leader may indicate the direction orally, by pointing, or by firing a tracer.

The TARGET DESCRIPTION should be brief and clear—for example, AUTOMATIC WEAPON, SNIPER, or TROOPS IN CLUMP OF TREES.

The RANGE may be announced orally or indicated by arm and hand signals.

TARGET ASSIGNMENT designates who is to fire at the target. If all personnel in the unit have been alerted and if it is desired that they all fire at the target, this element may be omitted.

The FIRE CONTROL element normally consists of the command COMMENCE FIRING or simply FIRE. It may, however, also include the command to FIRE FASTER, FIRE SLOWER, or CEASE FIRE.

OUTPOSTS

An outpost is a security detachment distributed at some distance from the main body of troops which are at a halt, in camp or bivouac, or in battle position. The purpose of an outpost is to protect friendly forces from observation and surprise by the enemy.

The location and nature of an outpost are determined by the enemy capabilities, terrain, and the location of the main body (platoon, company, or battalion). The strength and composition of an outpost vary with the distance, mobility, armament, and attitude of the enemy. Other factors affecting strength and composition include the time of day, size of command to be secured, degree of resistance desired, and special tasks assigned.

MISSION OF OUTPOSTS

The primary mission of an outpost is security. This mission is developed by any or all of the following:

1. Reconnaissance.
2. Observing and reporting information relating to activity of the enemy.
3. Preventing the enemy from gaining information.
4. Giving warning of a hostile attack.
5. Deceiving the enemy as to the location of the main body or the battle position.
6. Developing enemy dispositions and delaying the hostile attack to allow the main force to prepare for combat.

There are two basic types of outposts: GENERAL OUTPOSTS and COMBAT OUTPOSTS. A general outpost is established to delay and disorganize the advance of the enemy and to deceive him as to the true location of the battle position. A general outpost normally consists of larger forces than are available to a battalion; therefore, general outposts normally play no part in battalion combat operations.

A combat outpost covers the foreground of the battle position. It is normally the foremost element on the command. As a rule, the outpost is located from 800 to 2,000 yards from the main line of resistance or the camp or bivouac area.

A combat outpost consists of a series of outguards with appropriate sentinels and patrols. An outguard varies in strength from one fire team to a full platoon, depending upon the situation. Not infrequently, an outpost will consist of one squad. The squad leader (or other unit leader of an outpost) has the following duties in connection with outguard duty:

1. Checking to see that observation posts are well concealed and, at the same time, are able to observe the ground over which the enemy is expected to advance.
2. Checking to see that patrols are following the prescribed routes.
3. Passing on to his men all available information regarding both friendly and enemy forces, including any special orders.
4. Instructing his men as to what action to take in case of enemy attack.
5. Informing the platoon or company commander immediately of enemy activity.

Outguards must be ready for action at all times. Although their primary mission is observation, they will normally fire on small hostile reconnoitering groups.

The sentries of an outguard are designated observation posts. They are the lookouts who give the alarm in case of attack or other hostile activity. Frequently sentries are posted in pairs.

The patrols of an outpost conduct reconnaissance within the limits required by their security mission. A patrol executes reconnaissance in advance of the line of sentinels and in areas not covered by the sentinels. Patrols also maintain contact between elements of the outposts. Patrolling beyond the sentinels' line of observation is increased during periods of low visibility and at night.

COMBAT SIGNALS

Oral communication is often difficult or impossible under combat conditions. A system of arm-and-hand signals and of sound signals has therefore been developed. It is obvious that every man in a fire team must understand these signals. Since Constructionmen are required to serve in fire teams, Seabee personnel must learn arm-and-hand and sound signals before becoming Constructionmen. Starting with the Navy Training Course for Constructionmen, numbered NavPers 10630-C, these signals will be described in that course.

Practice in the use of combat signals is essential if they are signals to be used effectively. If you do not already know all arm-and-hand signals and audible signals, study the Landing Party Manual, Marine Corps Publications, or other sources where these signals are given. Several of the more common signals are shown and discussed in this chapter.

WHISTLE SIGNALS

As a rule, only three whistle signals are used, since a large variety could cause confusion.

The three commonly used are (1) ATTENTION TO ORDERS, (2) CEASE FIRING, and (3) HOSTILE AIRCRAFT or MECHANIZED VEHICLE.

Attention to orders is indicated by one short blast on the whistle. It is used to fix the attention on the unit leader who gives the signal and means that other signals, orders, or commands are to follow.

Cease firing is indicated by one long blast on the whistle. This signal is verified immediately by an arm-and-hand signal or by some other means.

Hostile aircraft or mechanized vehicle is indicated by three long blasts repeated several times.

SPECIAL SIGNALS

Special signals cover all the special methods and devices used to transmit commands or information. Rifle shots or automatic rifle bursts may be used if the entire command is acquainted with their meanings and the sound is distinct enough to be heard easily. A squad leader operating at night may find the use of raps on his helmet or rifle effective. Signals must, of course, be determined and practiced before they are used. Various pyrotechnic and smoke signals may be designated as signals to attack, withdraw, mark front lines, or indicate targets.

Certain special signals are standard for all branches of the armed services to indicate the approach or presence of hostile aircraft or mechanized vehicles. They are as follows:

1. Three long blasts of a whistle, vehicular horn, siren, or klaxon repeated several times.
2. Three equally spaced shots with rifle or pistol.
3. Three short bursts of fire from automatic small arms.

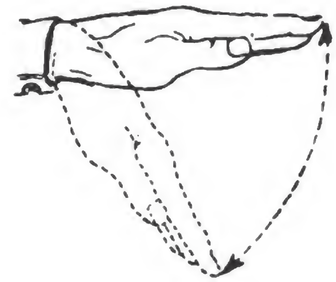
In daylight, the individual giving the signal should point toward the danger; at night, the alarm should be supplemented by voice warning to indicate the direction—for example, ENEMY TANKS APPROACHING BY THE NORTH ROAD or HOSTILE AIRCRAFT APPROACHING FROM THE WEST.

Unit leaders should devise special signals whenever they appear to be useful in a particular situation. Before devising a special signal for your unit, make certain that higher authority has not designated some other meaning to the same signal.

ARM-AND-HAND SIGNALS

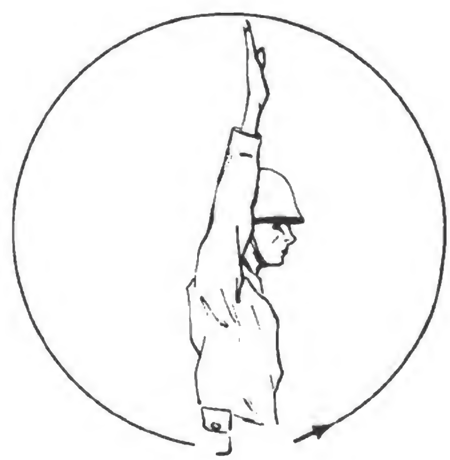
The Landing Party Manual shows 35 arm-and-hand signals to be used under conditions of combat. Certain basic rules which follow govern the use of these signals.

1. Subordinate leaders should repeat signals to their units whenever necessary to ensure that the signal has been received by all concerned.
2. A second signal should not be given before the first one has been executed.
3. If a signal is to be executed by a particular subordinate unit or units of a command, a signal designating the unit or units will precede the signal for the movement. For example, if a squad is to be signaled to form a column the signal SQUAD (fig. 10-9) should first be given before signaling FORM COLUMN. (fig. 10-10)



2.243

Figure 10-9.—Squad.



2.262

Figure 10-10.—Form column.

4. If a movement is to be executed in unison, the signal should be followed by the signal ARE YOU READY? (fig. 10-11) For example, if a squad leader desires each of his fire teams to form a wedge simultaneously, he should first signal FIRE TEAM (fig. 10-12) and then WEDGE (fig. 10-13); next he should signal ARE YOU READY? The fire team leaders must repeat the signal (When repeated by unit leaders the READY signal means I AM READY.) When the squad leader drops his arm after the fire team leaders have repeated the signal, all fire teams execute the signal simultaneously.

5. Signals requiring a change of direction have no connection with the direction in which the person who gives the signal is facing. Direction of movement is indicated by the direction in which the arm of the signaler points.

As previously mentioned, there are 35 arm-and-hand combat signals, some of which have already been discussed. A discussion of other common ones follows.

The PLATOON signal (fig. 10-14) is made by extending both arms forward toward the leader(s) or unit(s) for whom the signal is intended, palms down; describe large vertical circles with the hands.

2.256

Figure 10-11.—Are you ready? or (I) we are ready.

2.244

Figure 10-12.—Fire team.

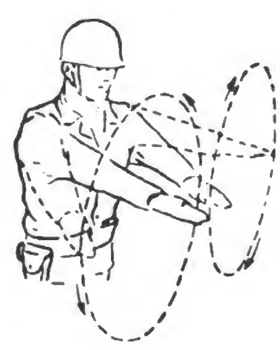
2.263

Figure 10-13.—Wedge.

The VEE formation (fig. 10-15) is signaled by extending the arms above the head at an angle of 45 degrees, forming the letter V with arms and torso.

SKIRMISHERS, RIGHT/LEFT (fig. 10-16) is indicated by raising both arms laterally until they are horizontal, with arms and hands extended, palms to the front. If it is necessary to indicate right or left, swing the arm and hand on the side toward which you desire the deployment to be made, upward until vertical and back immediately to the horizontal position. Repeat the swinging several times, holding the other arm and hand in the horizontal position until the signal is understood.

ECHELON RIGHT or ECHELON LEFT is signaled by facing the units to be signaled and extending the arm in the direction in which the unit(s) are to be echeloned, downward to the side at an angle of 45 degrees below the horizontal, palm to the front. Extend the other arm upward and to the side at an angle of 45 degrees, palm to the front. Extend the other arm upward and to the side at an angle of 45 degrees, palm to the front. (See figure 10-17.)



2.242

Figure 10-14.—Platoon.

2.247
Figure 10-15.—Vee formation.

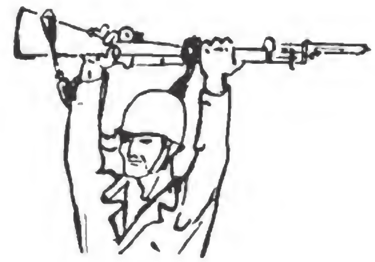
2.249A
Figure 10-16.—Skirmishers, right/left.

2.264
Figure 10-17.—Echelon right/left.

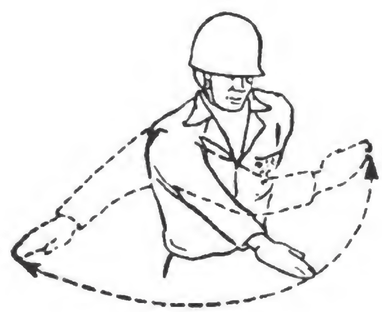
ENEMY IN SIGHT (fig. 10-18) is indicated by holding the rifle horizontally above the head with arms extended.

COMMENCE FIRING (fig. 10-19) is signaled by extending the arm in front of the body, waist high, palm down, and moving it through a wide horizontal arc several times.

CEASE FIRING (fig. 10-20) is signaled by raising the forearm in front of the forehead, palm to the front, and swinging it up and down several times in front of the face.



2.254
Figure 10-18.—Enemy in sight.



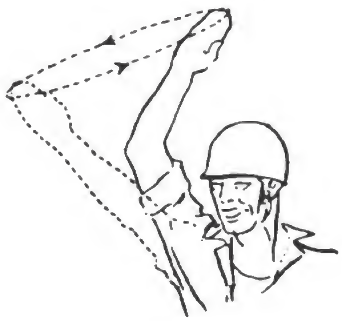
2.258
Figure 10-19.—Commence firing.

2.259
Figure 10-20.—Cease firing.

The ASSEMBLE sign (fig. 10-21) is made by raising the hand vertically to the full extent of the arm, fingers extended and joined, and describing large horizontal circles with the arm and hand.

FORWARD (fig. 10-22) is indicated by facing and moving in the desired direction of the march; at the same time, the hand is extended vertically to the full extent of the arm, palm to the front; the arm and hand are lowered in the direction of movement until horizontal.

The signal for HALT (fig. 10-23) is to carry the hand to the shoulder, palm to the front, then thrusting the hand upward vertically to the full extent of the arm and holding it in that position until the signal is understood.



2.261

Figure 10-21.—Assemble.

2.250

Figure 10-22.—Forward.

2.265

Figure 10-23.—Halt.

CHAPTER 11

ABC WAREFARE DEFENSE EQUIPMENT

INTRODUCTION

With the advent of the atom bomb, it is apparent that new tactical weapons are available to both enemy and friendly troops. For every new weapon developed there is a constant search for weapons, or devices to counteract the effect of that weapon.

The only defense against the blast of nuclear weapons, as with conventional weapons, is to be properly protected from the direct force and destructive phases of that particular warhead. However, there is a continuing danger from a nuclear explosion that does not exist after a conventional explosion. This is the harmful radiation that is emitted from a nuclear explosion, known as alpha particles, beta particles, gamma rays, and neutrons.

Because of the great unseen radiation dangers that will be present in the event of nuclear warfare, it will be necessary to use instruments that will make the personnel involved aware of the intensity of the radiation so that all possible precautions can be taken to reduce exposure. Even in peacetime, the danger is forever present for those who work in many of our laboratories and at the various nuclear reactor plants.

NUCLEAR RADIATIONS

Nuclear radiations given off by radioactive elements consist of four types, ALPHA PARTICLES, BETA PARTICLES, GAMMA RAYS, and NEUTRONS.

ALPHA PARTICLES are fast-moving helium ions. In the un-ionized (natural) state, the helium atom has a nucleus made up of two protons and two neutrons; around this nucleus revolve two electrons. When both electrons are stripped from the helium atom in the ionization process, the nucleus then carries two positive charges (two protons). The helium nucleus, with both electrons missing, is the alpha particles. The alpha particles that are emitted from the nucleus in atomic disintegrations are so large, relatively speaking, that they cannot penetrate a sheet of paper.

BETA PARTICLES are streams of fast-moving electrons that have been ejected from the nucleus following the conversion of a neutron into a proton and an electron. The electron becomes the beta particle. Beta particles are high velocity electrons and, since they are only 1/7500 as heavy as alpha particles, they travel several hundred times farther than the alpha particles. But even with this greater speed they cannot penetrate a sheet of aluminum more than a few millimeters in thickness.

GAMMA RAYS, as the name implies, are not particles at all but a form of electromagnetic radiation, very much like light rays or X-rays. Gamma rays move at the speed of light, 186,000 miles per second, and differs from light only in having a much higher frequency; or putting it another way, their wave length is much shorter. Gamma rays have the greatest penetrating power of the three forms of nuclear radiation explained. To reduce the effect of gamma rays following an atomic bomb explosion, it is necessary to use lead shielding several inches thick, or concrete several feet in thickness.

NEUTRON is a fourth type of radiation. As the name implies, it carries no electric charge. Because it is neutral it can enter into the nuclei of atoms of the human body and produce nuclear changes that might lead to artificial radiation. (Of course, this action is not limited to the atoms in the human body.) Destruction of the cell is the usual result, and the person who has been subjected to intense neutron radiation is likely to suffer serious injury, if not death as a result of the exposure.

UNITS OF RADIATION

Two different quantities are measured by radiac instruments: INTENSITY (or dosage rate) and DOSAGE (total amount of radiation absorbed). Intensity is measured in roentgens per hour (r/hr) or MILLIROENTGENS PER HOUR (mr/hr) and dosage is measured in ROENTGENS or milliroentgens. Roentgens is

the amount of X or gamma radiation which produces one electrostatic unit (esu) of charge per cubic centimeter (cc) of air at standard temperature and pressure (STP). This is the unit of exposure dose for X or gamma radiation.

Table 11-1 will give you a general idea of radiation effect measured in roentgens, on the human body.

MEASURING EQUIPMENT

The following portions of this chapter are intended to give you enough background information to familiarize you with the operating and maintenance procedures of the various types of radiac and gas alarm gear. The devices described in this chapter are not necessarily the only devices which you will be required to maintain. Some of these will become obsolete or will be modified to some extent. However, the basic operating and maintenance procedures will be somewhat similar.

You will NOT be held responsible for major repairs or overhauls; however, you will be required to perform appropriate field maintenance. You will probably be given specific instruction as to what type of maintenance you are to perform on these devices. USE THE APPROPRIATE INSTRUCTION MANUAL FOR ALL RADIAC AND GAS ALARM DEVICES YOU ARE TO MAINTAIN.

The devices with which you will work are designated by a joint electronics type designations system. A set containing an instrument, a carrying case, and other auxiliary equipment will have a number (such as the AN/PDR-18A radiac set). The meter within the set may have a different designation for example the meter IM-75/PDR-18A is a part of the AN/PDR-18A set. The letter after the last number indicates a modified model in the same series (for example, the set is a modified model of AN/PDR-18.)

Table 11-1. Probable Effects of Acute Nuclear Radiation Over Whole Body (20-KT Bomb; Burst Height, 2,000 Feet)

NOTE: Assume that personnel have had no significant prior exposure.

Range from ground zero (yards)	Acute dose (roentgens)	Probable effects
2,000	50 or less. .	No symptoms of sickness. No decrease in combat effectiveness.
1,750	100	Nausea and vomiting for about 1 day in approximately 2 percent of personnel. No evacuation needed; all able to perform duty.
1,650	150	Nausea and vomiting for about 1 day in approximately 25 percent of personnel. No evacuation expected.
1,550	200	Nausea and vomiting for about 1 day in approximately 50 percent of personnel. Evacuation of about 25 percent by end of 1 week (par. 87). No deaths anticipated.
1,450	300	Nausea and vomiting in all personnel on first day. Evacuation of all as soon as combat conditions permit. About 25 percent deaths, reducible by adequate treatment. Survivors ineffective for full military duty for about 3 months.
1,350	450	Nausea and vomiting in all personnel on first day. Evacuation of all as soon as combat conditions permit. About 50 percent deaths, reducible by medical treatment. Survivors ineffective for full military duty for about 6 months.
1,250	650	Nausea and vomiting in all personnel within 4 hours. Evacuation of all as soon as combat conditions permit Up to 100 percent deaths. Survivors ineffective for full military duty for over 6 months.

SURVEY METERS

The AN/PDR-18A radiac set is a portable instrument used to detect and measure high intensity gamma radiation.

The detection of gamma radiation is accomplished by means of a sensitive phosphor element.

DESCRIPTION

The radiac set, AN/PDR-18A (fig. 11-1) consists of a carrying case, the IM-75/PDR-18A radiacmeter, and spare parts for the radiacmeter.

The radiacmeter IM-75/PDR-18A contains a sensitive phosphor, a photomultiplier tube, a switching circuit for the manual selection of intensity ranges, a cathode follower triode, a microammeter, a vibrator type regulated high voltage power supply, and dry cell batteries. The instrument case of the IM-PDR/18 is equipped with a shoulder strap. A handle, located on the front panel as shown in figure 11-1, provides a hand grip for the operator to use when holding the radiacmeter in a position where the microammeter can be read. A meter range selector switch is located to the right of the handle on the front panel. A push-button for the control of meter dial illumination is located on the handle. A knob for zero setting the microammeter is located in the upper right corner of the front panel, a similar knob is located just above the selector switch on the front panel for the calibration of the microammeter. The meter ranges are 0.5, 5, 50, and 500 roentgens per hour. The meter scales are mechanically changed by the range selector switch so that only the calibration for the selected range appears on the dial of the microammeter. To indicate the degree of personal danger, each scale has a different background color. The color of the 0.5 scale is yellow; the 5 scale is orange; the 50 scale is pink; and the 500 scale is red.

3.174.1

Figure 11-1.—Radiac set AN/PDR-18.

OPERATING CONTROLS

The operating controls for the IM-75/PDR-18A are shown on figure 11-2.

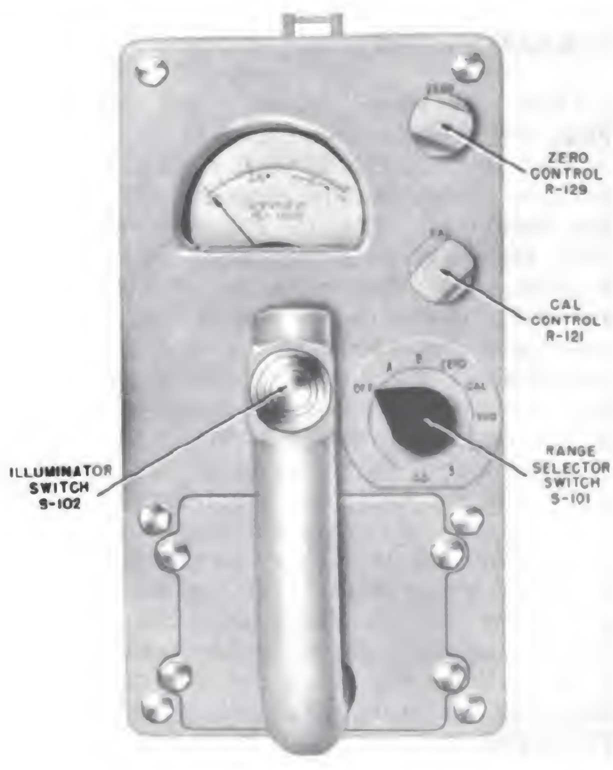
The RANGE SELECTOR SWITCH is a nine position switch that is mechanically geared to the meter dial. When the range selector switch is in the OFF, A, B, ZERO, or CAL position, a plain white dial marked with ZERO, A, B, and CAL shows on the meter face. When the range selector switch is in the A position, the condition of the filament battery is indicated by the position of the meter needle with respect to the marker A on the meter dial. When the range selector switch is in the B position, the voltage of the batteries supplying the power to the vibrator is indicated by the position of the meter needle with respect to the marker B on the meter dial. When the range selector switch is in the ZERO position, the meter needle may be adjusted to zero with the ZERO control. When the range selector switch is in the CAL position, the radiacmeter may be calibrated by adjusting CAL control for full scale deflection. The remainder of the positions of range selector switch provide different dial scales on microammeter for the different ranges of operation of the radiacmeter.

OPERATION

To place the IM-75/PDR-18A in operation the RANGE SELECTOR switch should be turned from OFF to the A position. The meter needle should be deflected to the right of the marker A on the meter scale. Next, turn range selector switch to the B position. The meter needle should deflect to the right of the B marker on the meter face. Turn range selector switch to the ZERO position and adjust ZERO control for zero deflection on the meter scale. Turn range selector switch to the CAL position and adjust CAL control until full scale deflection is obtained.

CAUTION: When turning the range selector switch to the CAL position, make sure that the switch is fully engaged in the detent provided for that position. Failure to do this may cause inaccurate calibration when CAL control is adjusted for full scale deflection.

Turn range selector switch to the 500 position. The radiacmeter is now ready for measuring radiation. Full scale deflection indicates 500 roentgens-per-hour. If the meter does not show sufficient deflection to read the radiation accurately, shift to the 50 position of range selector switch. If deflection sufficient for an accurate reading is yet not obtained, continue to reduce the setting of the range selector until a satisfactory reading is obtained.



3.174.2

Figure 11-2.—Radiacmeter IM-75/PDR-18, operating controls.

PREVENTIVE MAINTENANCE

The object of preventive maintenance is to anticipate as far as possible the occurrence of troubles and to take steps to prevent them. Preventive maintenance includes periodic cleaning, painting, and inspection.

The front panel assembly and main housing should be checked for cleanliness and scratches. Any scratches in the paint should be retouched with a brush. The screws that secure the front panel to the instrument case and the screws that secure the battery box assembly to the front panel, should be checked to see that they are tight.

NOTE: In all cases where the fungus-proofing film is broken during adjustment of the apparatus, recoat the break with fungus-proofing compound. Specification MIL-V-173, by brush application.

You should never attempt any extensive or complicated repairs since a high degree of technical skill, knowledge, and experience are required. By means of simple tests and procedures, you can perform simple preventive maintenance, and in case of emergencies, effect certain repairs. Routine checks to determine whether the equipment is performing satisfactorily should be made each time the equipment is used. Figure 11-3 shows the checks that should be performed. Any maintenance required as a result of these checks should be limited to the replacement of batteries. Troubles which are not eliminated by the replacement of the batteries should be referred to the proper authority.

Battery Replacement

Figure 11-4 shows radiacmeter IM-75/PDR-18A with the battery box removed (BT-101). To replace the batteries in the radiacmeter, loosen the four battery box cover retaining screws, H-107, which fasten the battery box cover. Remove battery box, BT-101, and place alongside instrument, as shown in figure 11-4.

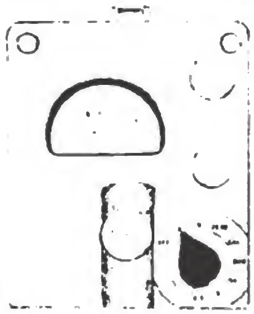
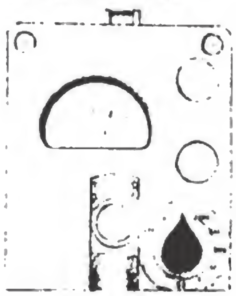
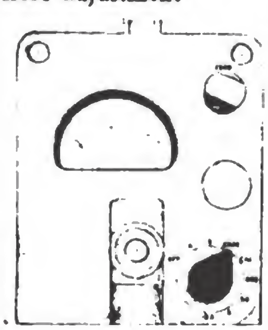
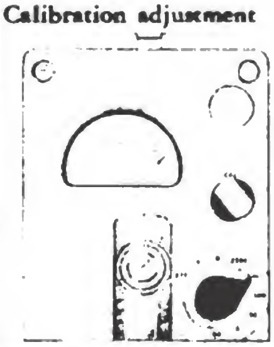
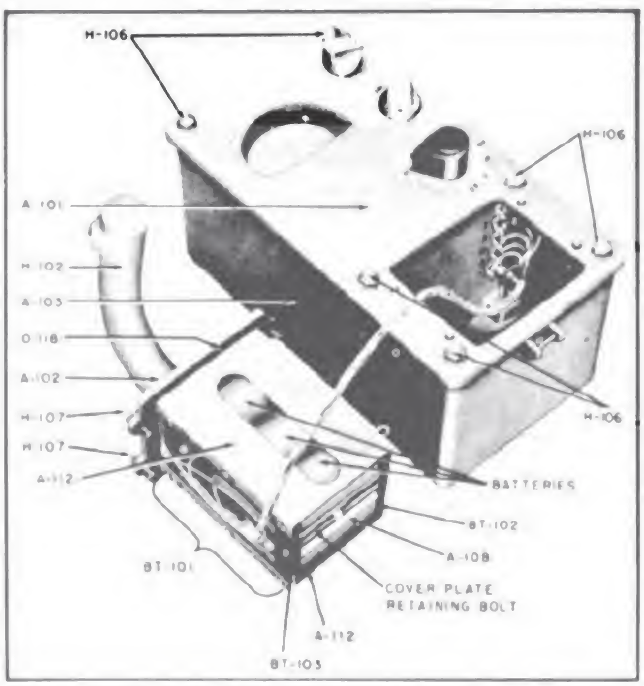
WHAT TO CHECK	HOW TO CHECK	PRECAUTIONS
Filament Battery Voltage 	Range selector switch S-101 in A position. Read microammeter M-101.	Reading should not be to left of A marker.
Vibrator Power Supply Primary Voltage 	Range selector switch S-101 in B position. Read microammeter M-101.	Reading should not be to left of B marker.
Zero adjustment 	Range selector switch S-101 in ZERO position. Read microammeter M-101, adjust ZERO control R-129.	ZERO reading on microammeter M-101 should be obtained.
Calibration adjustment 	Range selector switch S-101 in CAL position. Read microammeter M-101, adjust CAL control R-121.	Set full scale deflection on microammeter M-101. CAUTION: when turning the range selector switch S-101 to the CAL position, make sure that the switch shaft is fully engaged in the detent provided for that position.

Figure 11-3.—Routine check chart. 26.141

Remove the battery box cover plate, A-108, by removing the cover plate retaining bolt. Remove batteries from the battery box, BT-101, by inserting a finger in the slot in side plate, A-112, and pushing the batteries, one by one, out of the open bottom of the battery box. When replacing with new batteries, JAN type BA-30/U batteries are recommended for replacement purpose. Insert the new batteries in the battery compartment. When inserting the batteries, be careful to observe the specified polarity, which is stamped on the side plates, A-112. Note that the three batteries in the bottom row are installed with their positive terminals on the right side. Before replacing the battery box cover plate, A-108, check the battery voltages as described in figure 11-3. If these voltages do not check correctly, first examine for correct battery polarity inside the battery box, and then try different batteries. If the voltages then fail to appear, the set should be sent to the radiac repair shop.

When reinstalling the battery box, BT-101, in the recess provided in the instrument case cover, A-101, carefully coil the connecting cable in a single vertical loop alongside contact mounting plate BT-103. DO NOT ALLOW THE CONNECTING CABLE TO COIL UP AT THE BOTTOM OF THE RECESS.



3.174.3

Figure 11-4.—Radiacmeter IM-75/PDR-18, Battery box removed.

AN/PDR-27CY (DESCRIPTION)

The AN/PDR-27 (any letter designation) is a portable, watertight, battery-operated instrument used for detecting and measuring combined beta and gamma radiations from 0 to 5 milliroentgens per hour, or gamma radiations alone from 0 to 500 milliroentgens per hour.

The radiac set consists of a radiacmeter IM-140/PDR-27CY which is the main unit; it is equipped with a carrying handle, and also may be carried by an externally connected shoulder harness. Radiac Detector DT-53B/PDR-27 is a probe attached externally, by means of a flexible cable, to the radiacmeter. The detector is normally carried in an external well on the radiacmeter and can be easily removed. When measuring gamma radiation, the detector can be used in or out of the well; beta radiation, however, can only be detected when the detector is removed from the well and the beta shield on the probe is moved aside. The radiacmeter also houses the chassis for electronic gear, an indicating meter, and dry batteries. Case CY-963A/PDR-27 is a light-weight carrying case which houses the radiacmeter, radioactive test sample MX-1083B/PDR-27, headset H-43/U, harness ST-119/PDR-27, spare tubes, two wrenches, and two copies of the instruction book. The complete radiac set AN/PDR-27CY is illustrated in figure 11-5.

The carrying case houses all other radiac set units. It is equipped with carrying handles and hasps, and is so constructed that it can be completely disassembled for decontamination. A spare parts compartment is provided in the case.

The radiacmeter consists of three castings. One casting is made up of the handle which is cast integrally with a plate which serves as a water-tight cover for the battery compartment. The second panel casting provides the means for mounting the electronic chassis, meter, range switch, headset jack, and a compartment for the batteries. The remaining casting completes the waterproof enclosure and provides a well at one end to hold the detector probe. All joints between castings are made watertight by the use of rubber O ring gaskets, and screws to draw the joints tight.

Mounted on the panel are an indicating meter, a range switch, and a headset jack.

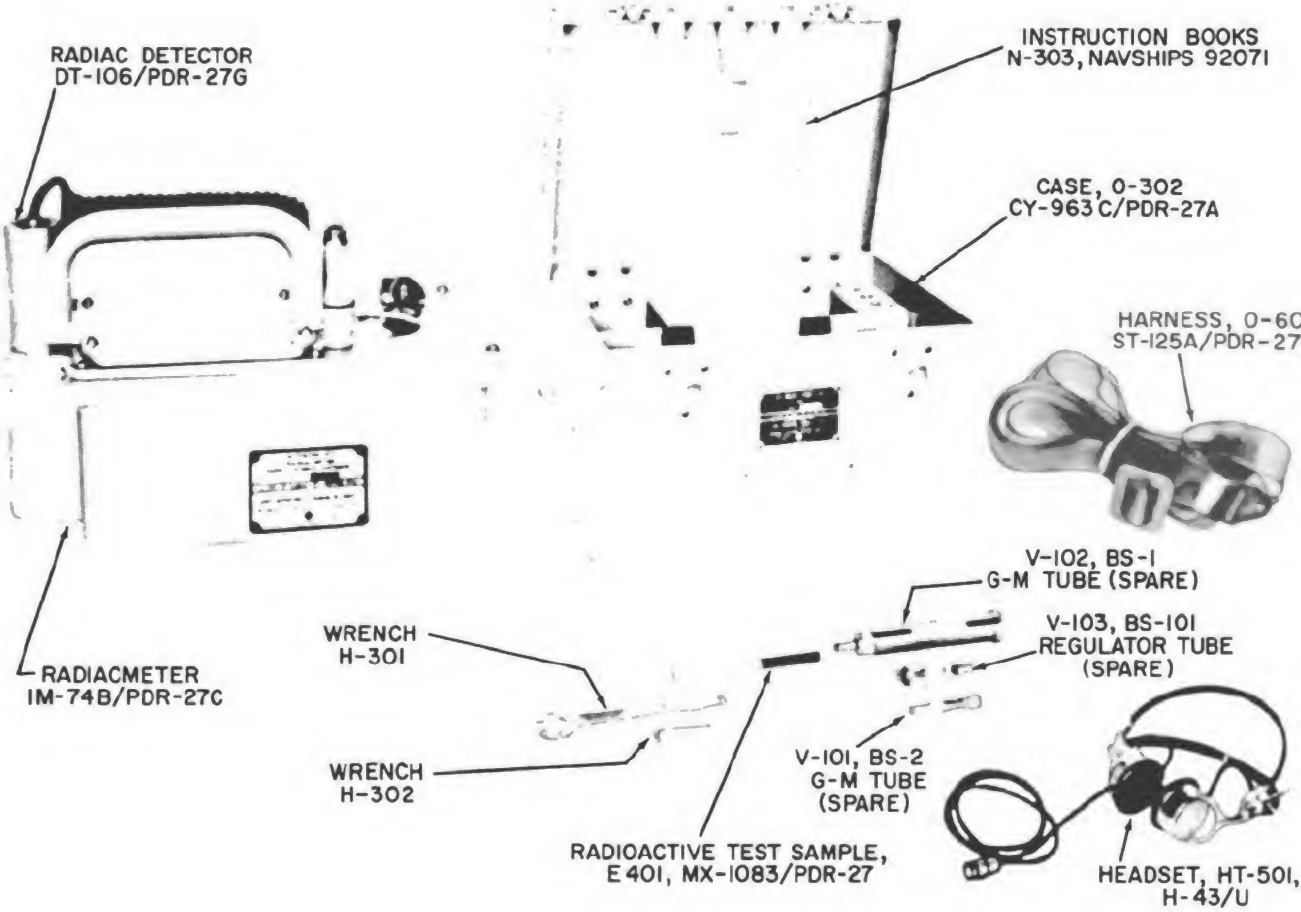


Figure 11-5.—Radiac set AN/PDR-27 CY.

Illustrated in figure 11-6 is the front panel of the radiacmeter. Mounted on the underside of the panel are the electronic elements of the equipment including a plug-in unit containing three subminiature tubes and their associated circuit elements.

The indicating meter face has a window behind which is placed a meter card with four colored scales. The meter card is carried on a shaft turned by a sprocket gear. Rotation of the card shaft places the scales, one at a time, within the meter face window; only one scale at a time is visible.

The range switch is a three-wafer, five section, switch with six operating positions selected by the switch shaft detents. Mounted on the switch shaft is a sprocket gear, connected by a spring-loaded chain with the gear on the card shaft. As the range switch is turned to the various operating positions, the card shaft positions the corresponding scales of the meter card in the meter face window.

The battery power is conveyed to the electronic chassis through the wall of the battery compartment by means of a waterproof feed-through terminal strip. Eight single cell D type batteries are enclosed in a compartment within the plastic case located in the watertight battery well housing of the AN/PDR-27CY. This plastic case contains both the batteries and the vibrator power supply. The batteries are located in separate compartmented area in the upper portion of the case, to facilitate easy battery replacement.

The carrying handle is constructed to allow space for the radiac detector flexible cable when the detector is stowed in its well.

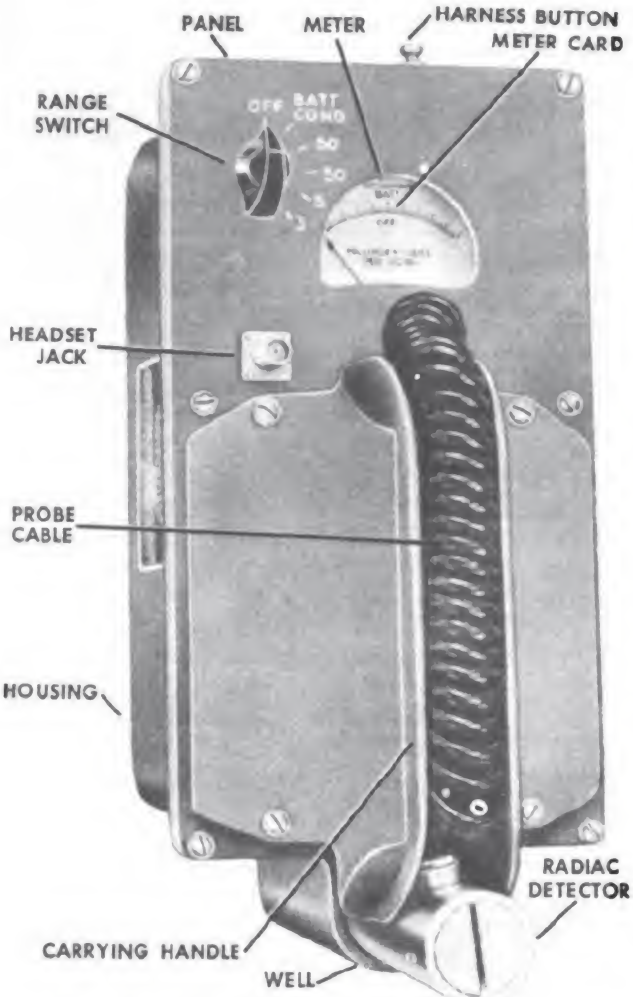


Figure 11-6.—Radiacmeter, front view.

The radiac detector is a probe consisting of a Navy type BS-1 G-M tube contained in a cylindrical metal housing. At one end, the housing is closed by a threaded plug; at the other end, a threaded retaining ring bears against the body of the Geiger-Muller (G-M) tube but leaves a mica window exposed. The G-M tube is supported by a rubber gasket at one end. Electrical connection to the tube is made by a kinkproof flexible cable which passes through a waterproof packing gland in the cylindrical housing. A spring-retained metal shield covers the mica window of the G-M tube. When the shield is over the window, beta radiations are prevented from entering the tube; the shield can be swung aside when beta-plus-gamma radiations are to be detected. A metal guard is secured directly over the window.

CAUTION: Since the mica window is only 0.0005-inch thick, it is extremely fragile. Do not touch the window under any circumstances, as damage to the tube will result. Do not rely on the guard to protect the mica window; the guard openings are large enough so that sharp objects can pass through and pierce the window.

The headset provides the operator with aural (sound) indications of radiation intensity when plugged into the jack on the radiacmeter front panel.

The shoulder harness, an adjustable strap made of a nonabsorbent plastic, is used for carrying the radiacmeter and probe during operation. Metal clips on the harness fasten to harness buttons secured to the radiacmeter housing.

The radioactive test sample consists of a plastic tube containing 7 micrograms of radium. The tube is flattened at one end to facilitate handling. The radium provides a radiation source that permits the operator to ascertain the operating condition of the radiac set when no known radiation field is available.

WARNING: Because radium is potentially dangerous, serious skin and internal burns may result if the test sample is held close to the skin for prolonged periods. When using the test sample, handle it only long enough to ascertain the operating condition of the radiac set; then replace it in its storage compartment in the carrying case. If the radio-active test sample is broken, notify your commanding officer immediately and request disposal instruction.

OPERATION

To operate the radiac equipment remove it from the case, attach the shoulder harness, and plug in the headset. The condition of the battery is then checked by turning the range switch to BATT COND. The meter pointer should rest at the right of the line marked BATT on the meter face. Set the range switch at either 500, 50, 5, or .5, depending on the intensity of the radiation. Check for the presence and the intensity of radiation by observing the meter reading or the frequency of the clicks in the headset. When necessary, illuminate the meter face by tilting the radiacmeter so that the panel is in a 45-degree position. When the combined beta and gamma radiation from an object is to be measured, turn the range switch to .5 or 5,

remove the radiac detector from the well of the radiacmeter, move aside the beta shield on the probe, point the probe at the object to be investigated, and move the probe close enough to the object to obtain a meter indication.

In order to stop the equipment turn the range selector switch to OFF. To stow the equipment remove the harness and headset from the radiacmeter, replace the radiac detector in the well of the radiacmeter. If the detector does not slide easily into the well, or if the cable does not coil tightly over the handle, rotate the probe so as to add or subtract turns to the coiled cable until the detector can be readily stowed. Unhook the radiacmeter from the shoulder harness, and remove the harness. Stow the radiacmeter, harness and headset in the carrying case.

MAINTENANCE

Check the condition of the batteries by turning the range switch S-101 to BATT COND position. The pointer on the meter should read to the right of the line marked BATT in the center of the meter scale. If the meter reading is low, the batteries are weak, and should be replaced. If batteries have corroded, clean battery compartment thoroughly.

To install batteries remove the radiacmeter from the carrying case and remove the four screws securing the handle and cover of the battery compartment. Remove the cover, then remove the weak or defective batteries. Replace with new batteries, and replace cover. Replace the four screws securing the cover and tighten. The screws must be tightened equally on all sides, or rubber gasket will be damaged.

Preventive maintenance is performed on equipment (usually when the equipment is not in use) to keep it in good working order so that there will be minimum interruptions in service. The routine maintenance which you are to perform is given in table 11-2.

DOSIMETER

The IM-9F/PD (fig. 11-7A) is a pocket radiacmeter which is of the instant reading type, having a scale of 0 - 200 milliroentgens (mr). The instrument measures and indicates the accumulated dose of X and gamma radiation to which the wearer has been exposed. At one end of the radiacmeter is an optical eyepiece and at the other end is the charging contact. A scale calibrated in mr is mounted in such a manner that the amount of radiation to which the wearer has been exposed can be read directly by holding the radiacmeter up to a source of light and looking into the eyepiece.

Part B of figure 11-7 shows the meter indicator at zero, which indicates it is sufficiently charged.

Part C of the above figure shows the scale reading after the instrument has been exposed to 83 mr of gamma radiation.

A radiac-detector such as the detector charger PP-354C/PD is required to keep it charged.

The IM-107/PD pocket radiac-dosimeter (fig. 11-8) is similar to the IM-9F/PD. It can be charged with either the radiac detector charger PP-311A/PD or PP-354C/PD (figs. 11-9A&B).

MAINTENANCE

Since pocket types of radiacmeters are hermetically sealed, no corrective maintenance can be performed in the field. These instruments are very delicate and are sensitive to dust and moisture as well as rough handling (shock). Dust and moisture in the charging end of the chamber will make charging difficult. This can be corrected by using a mild stream of dry air directed on the end of the chamber to remove dust particles and moisture collection.

Cleaning and decontamination can be performed by removing the clip and washing both the barrel and clip with soap and water.

To field check the instruments, charge to zero on the scale in a space free from radioactivity. Observe leakage on the scale for a period of 4 to 8 hours. Reading should be very near zero. If it is not, consider the unit defective and return to the nearest radiac repair facility for further testing, and possible replacement.

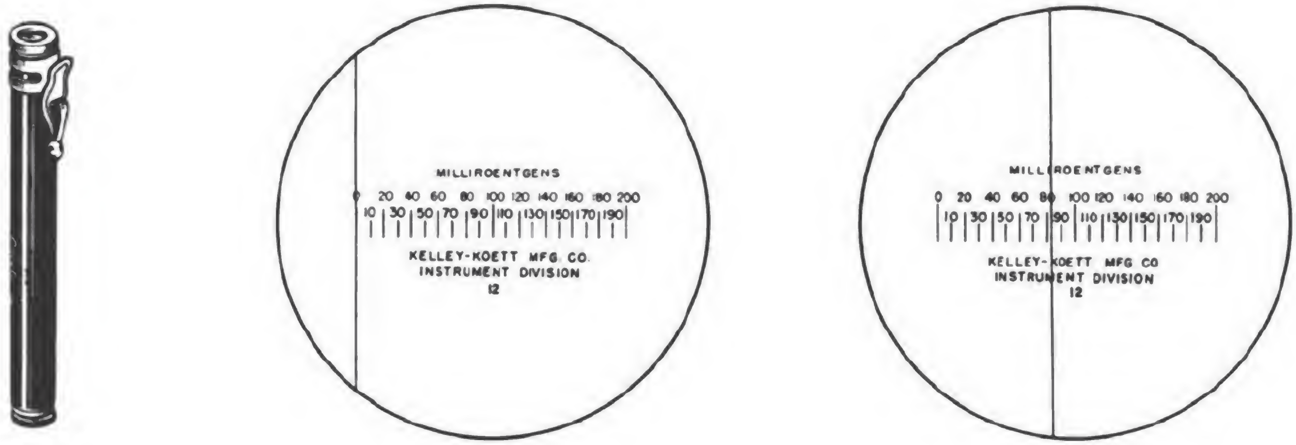
In stowing the instruments, they should be wrapped tightly in a plastic bag, "Saran Wrap", or similar material and stowed in a dust free area.

DT-60/PD RADIAC DOSIMETER

The DT-60/PD radiac dosimeter (fig. 11-10) is a non-self-indicating personnel dosimeter

Table 11-2. -- Routine Maintenance Check Chart.

What to Check	When to Check	How to Check	Precautions
1. Battery condition.	Weekly	Turn range switch to BATT COND. Meter pointer should rest at right of red line marked BATT.	Return range switch to OFF.
2. Exterior surfaces of radiacmeter, radiac detector, and shoulder harness.	Weekly	Wipe with a clean, dry cloth, removing all dirt and dust.	None.
3. Radiacmeter front panel screws.	Weekly	Tighten with screw driver.	Do not tighten excessively.
4. Range switch knob.	Weekly	Rotate knob. If loose, tighten setscrew with screw driver. Check to see that knob rests snugly against gasket. If it does not, loosen setscrew, push knob tightly against gasket and re-tighten setscrew.	Do not tighten setscrew excessively.
5. Radiac detector plug.	Weekly	Remove all dirt from plug. Obtain special wrench symbol H-301 from carrying case. Insert rounded end of wrench into plug slot, and tighten.	Do not tighten excessively.
6. Packing nut at both ends of radiac detector cable.	Weekly	Tighten with open end wrench.	Do not tighten excessively.
7. Radiacmeter circuit.	Monthly	Check radiacmeter with radioactive test sample. (See Section 3, par. 3.)	The radioactive test sample should be used only to check on whether or not the radiacmeter is operating. It should not be used as an accurate means of calibrating or checking sensitivity of this unit. If reading decreases vertically, investigate and correct cause.
8. Headset	Monthly	Remove dirt. Check tightness of screws and connections.	None.



A B C

A. Pocket radiacmeter IM9F/PD(A)
B. Charged radiacmeter
C. Radiacmeter scale reads 83 mr

26.143

Figure 11-7.—Pocket radiacmeter IM9F/PD(A) and scale indications for two conditions of charge.

26.144

Figure 11-8.—IM-107/PD radiacmeter.

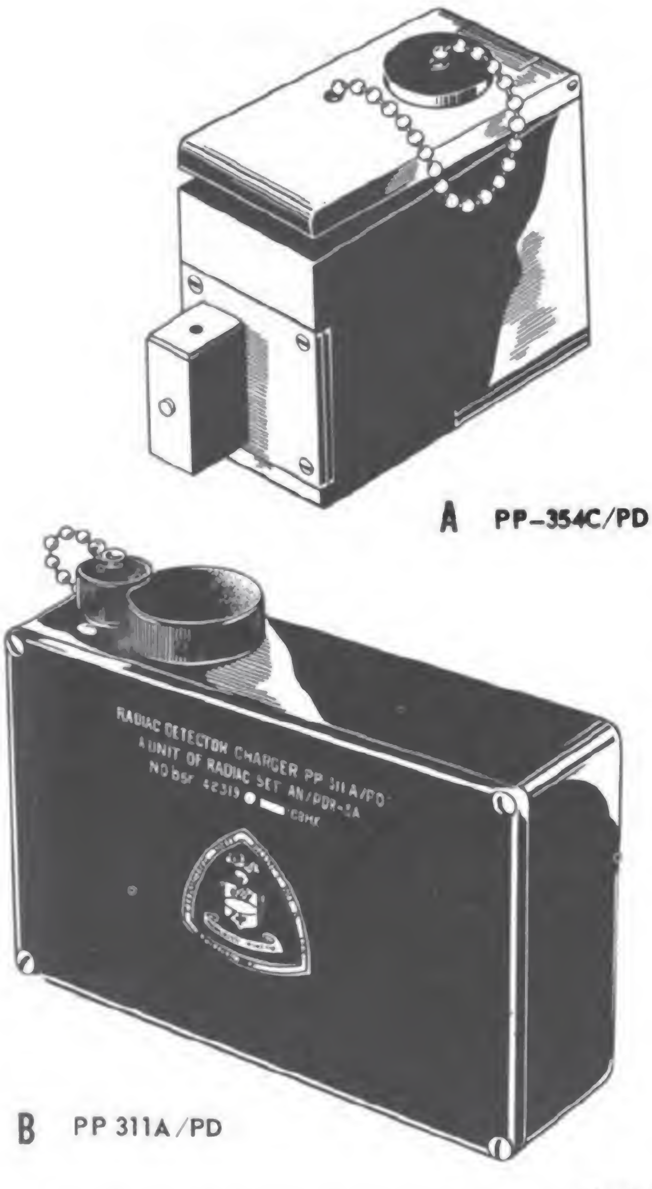
which is worn about the neck as a pendant. The instrument detects the accumulated doses of X or gamma radiation from 0 to 600 roentgens. It is sensitive to rough handling. It requires an associated radiac computer-indicator CP-95/PD for reading.

No corrective maintenance can be performed. Replace damaged or defective radiac-detectors. Clean and decontaminate by washing the entire assembly with soap and warm water.

COMPUTER INDICATOR

The CP-95/PD computer indicator (fig. 11-11) is a portable piece of equipment designed for computing and indicating the total amount of X and gamma radiation to which the DT-60/PD radiac detector has been exposed. It operates from a 120-volt, 60 cycle, a-c power source.

The entire equipment consists of one unit. A cover assembly (fig. 11-12A), held by four latch fasteners, encloses the front panel. You will notice that the panel (fig. 11-12B) contains a roentgens-indicating meter with two scales, 0 to 200 roentgens (black) and 0 to 600 roentgens (green), a red indicating lamp, and two meter illuminating lamps (not visible). In addition, a range toggle switch (for changing meter ranges), a power switch, two potentiometer controls, a power cable receptacle, and three fuses, one of which is a spare. The lower portion of the front panel contains a horizontal opening with a spring-loaded door through which a pivoted sector and skillet assembly can be rotated. The sector and skillet assembly contains three recesses: one remains empty, one contains a calibration standard, and the third is for the insertion of the radiac detector DT-60/PD which is to be



A. Radiac detector charger PP354C/PD
B. Radiac detector charger PP311A/PD

Figure 11-9.—Radiac detector chargers.

read. The assembly can be returned by means of an attached telescopic sector handle (test lever), into the housing of computer-indicator to locate anyone of these recesses under an ultraviolet light. A rubber stop is provided to prevent rotation of the calibration standard outside the case during operation. The top of the case contains a nameplate, instruction plate, carrying handle, and two protruding pins for opening the DT-60/PD radiac detector.

The front cover assembly (fig. 11-12A) contains three additional fuses, two Allen wrenches for use in the disassembly of the equipment, two small pin wrenches for opening the DT-60/PD detector, a large spanner wrench, and the power cable assembly.

OPERATION

To operate the computer-indicator it must first be connected to a 120-volt a-c source of power. Then proceed to operate the equipment in the following manner:

1. Rotate the sector handle (test lever) (refer to figure 11-12B for location of parts) outward and extend the lever until it catches in its detent.
2. Rotate the POWER switch S101 in its START position until the red indicator lamp, I103, located in the meter face, lights; then release the switch. It will return to its ON position and the red indicator lamp will go out. Allow the equipment to warm up for 3 to 5 minutes.
3. Place the meter-range toggle switch, S102, in its 200 R(roentgens) position.
4. Place the test lever to its CHANGE DT-60 position.
5. Remove the cover of the DT-60/PD by using the wrenches provided in the front panel cover assembly or the two pins located on top of the equipment near the carrying handle. The DT-60/PD can be held in the hand and the small pin wrench used to unscrew the cover. Should the cover be too tight to open with the pin wrench, then use the large spanner wrench mentioned earlier (the large spanner acts as a vise, keeps the base of the DT-60/PD from rotating) to hold the radiac detector, while you unscrew the cover with the wrenches provided or two pins located on the top of the equipment mentioned above.

NOTE: Be sure the DT-60/PD's are free of dirt or dust before reading. Be sure to avoid touching the enclosed glass once the cover is removed from the radiac detector DT-60/PD. Dirty or greasy fingertips are fluorescent and will give erroneous radiation indications. Soap and water may be used to clean the glass portion and the case of the radiac detector.

6. Insert the base (which contains the enclosed glass) of the dosimeter into its position, marked DT-60, in the sector and skillet assembly. Be sure it is seated on the locating pins.

3.177

Figure 11-10.—Radiac detector DT60/PD.

7. Rotate the sector handle until it detents in its CAL A position.

8. Adjust the A ADJ control R138 until the black meter needle coincides with the A position on the meter scale.

9. Rotate the sector handle to its CAL STD position.

10. Adjust the CAL ADJ control R124 until the black meter needle coincides with the fixed red meter pointer.

11. Repeat the adjustments until the black meter needle coincides with both the A position and the fixed red pointer, when the sector handle is CAL A and CAL STD positions, respectively.

12. Rotate the sector handle to its READ position (extreme counterclockwise) and read the roentgens as indicated by the black meter needle. (Do not attempt to repeat readings for greater accuracy, unless readings are being made for special purposes.)

13. Should the meter indicate a reading above 200, throw the range switch, S102 to its 600 R. position and read.

14. For further readings, begin with number 3.

MAINTENANCE

There is very little maintenance that you can do. The operating procedures (through 14) are an integral part of the routine check. The only thing you can do is to follow the above mentioned operating procedures to make certain that each reading obtained is correct.

NOTE: You shall not perform any emergency maintenance procedures without proper authorization. This equipment employs voltages which are dangerous and may be fatal if contacted by personnel. Extreme caution must be exercised when anyone is working with this equipment.

11.362.1

Figure 11-11.—Radiac,computer-indicator. CP-95/PD.

DOSIMETER CHARGER

The radiac detector charger PP-354C/PD (fig. 11-9A) is used to charge radiacmeters (dosimeters) IM-9F/PD and higher, IM-50/PD series, IM-20/PD and IM-19/PD series or similar types. This charger is an electrostatic type generator capable of generating 0 to over 180-volts, d-c by slowly turning the charging knob in a clockwise direction to bring hairline in the dosimeter to zero.

The charger PP-354C/PD is contained in a watertight metal case measuring 2 7/16 inches long by 1 inch wide by 2 inches high, overall. The hinged top section of the case contains the upper part of the charging socket, which continues into the body of the case. A removable plug closes the charging socket when it is not in use and the plug is secured to the charger by a length of bead chain. The bar-type operating knob for the charger is mounted on one end of the case. A window is provided in the bottom of the case to transmit light to the user of the radiacmeter.

OPERATION

The operation procedures for the radiac detector charger are given and illustrated in figure 11-13.

MAINTENANCE

The radiac detector charger PP-354C/PD cannot be repaired because it cannot feasibly be disassembled. Therefore a faulty charger should be removed from use and turned into the nearest repair facility.

The exterior surfaces of the charger can be cleaned with a clean lintless cloth. Rub gently over all surfaces. Do not use any solvent, especially alcohol, on the EXTERIOR surfaces.

Particles of dust or lint in the charging socket can usually be removed with a stream of clean dry air. Exceptionally stubborn particles may have to be flushed out carefully with pure water-free ethyl alcohol. Use the least amount of alcohol possible, then evaporate it with blasts of clean dry air.

CAUTION: Do not blow the breath into the charging socket to clean it. Permanent impairment of socket insulation may result.

Moisture resulting from condensation can be removed by heating the charger with a 60-watt bulb. Place the bulb about 6 inches away from the charging socket opening and leave it there for about 15 minutes.

NOTE: After cleaning the charger by any of the methods described above, it must be checked by charging two or more radiacmeters several times. Any evidence of imperfect operation, such as leakage or difficulty in charging, should warrant removing the charger from use.

CAUTION: Maintenance personnel must always be cognizant of the fact that radiac equipment is used for the primary purpose of protecting human life and health, and for that reason they should not permit the use of faulty radiac equipment.

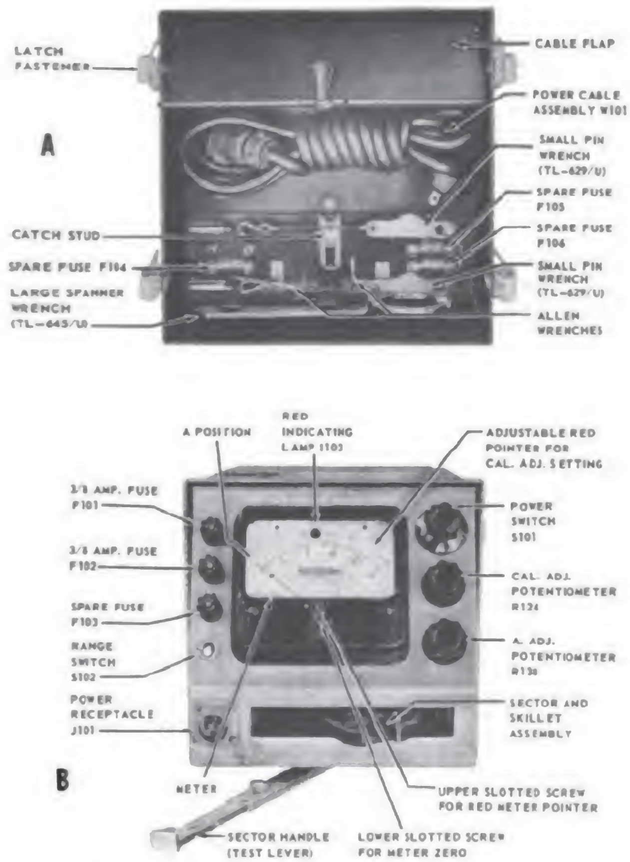
AIR SAMPLER

The air particle sampler, HD-251/UD (fig. 11-14) is intended for use in any closed space where airborne microscopic radioactive particles are likely to be present. By measuring a sample volume of air, a direct evaluation of the concentration of radioactive material may be read on AN/PDR-27 series radiac sets, or counted with a suitable G-M tube and scaler.

The air sampler consists of the air moving turbine, metering unit, power cord, filter papers, two filter holders, and a meter cap.

OPERATION

To use the air particle sampler, open the top of the air mover case and remove the power



A. Front cover accessories 11.362.2
B. Front panel controls and accessories

Figure 11-12.—Radiac computer-indicator CP-95/PD.

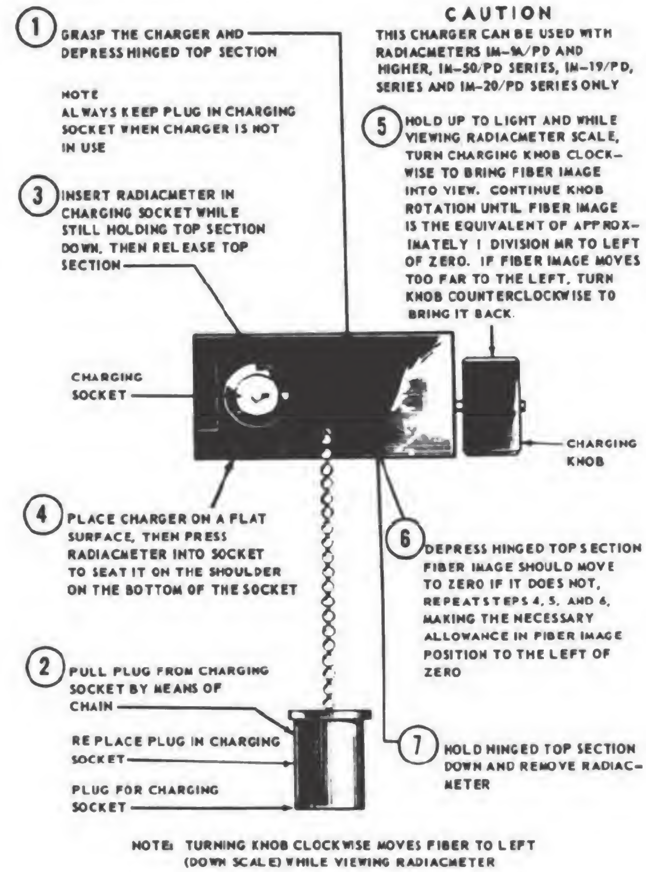


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Figure 11-13.—Radiac detector charger PP-354-C/PD and operating instructions.

supply cord, filter holder, and filter. Fit the filter into the holder and plug the holder into the inlet opening. Be sure the air meter is set at zero. You then place an AN/PDR-27 series radiac set in a location that is practically free of any radioactivity, at any rate in a location that has a reading of less than 0.1 mr/hr.

Place the power cord plug into a 110-volt, 60 cycle, a-c power source; and make sure the air sampler switch is in the OFF position. Now turn the switch to the ON position and take a sample of 20 cubic meters of air as indicated by the flow totalizer.

WARNING: Once the unit is turned ON, DO NOT turn it off until the air mover motor is up to full speed.

After collecting the sample of the air, turn the switch to the OFF position and remove the plug of the cord from the power source. DO NOT REMOVE THE PLUG WHILE THE SWITCH IS IN THE "ON" POSITION. Remove the filter holder with the filter in place, and carry it to the AN/PDR-27 to measure the amount of radioactivity picked up by the filter.

MAINTENANCE

The air particle sampler, HD-251/UD, is a sealed unit, requiring no repair on the major units. In the event of failure within the air mover unit, the sampler should be returned to the manufacturer for servicing. About the only thing you can do is to check the power cord for worn or frayed insulation, broken or cracked terminals or connectors. If any above mentioned conditions exist, replace the cord.

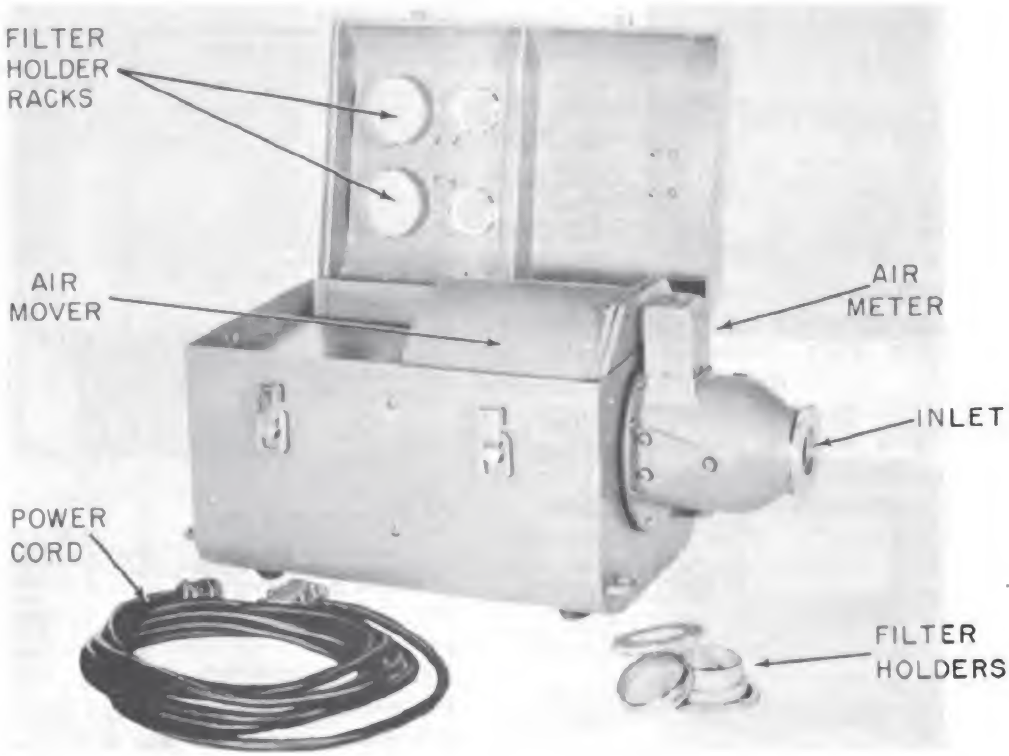

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Figure 11-14.—HD 251/UD equipment.

GAS ALARM (M6A1)

The M6A1 Automatic Field Alarm (gas) (fig. 11-15) is a completely self-contained device for detecting the presence of G-agents in the air. It is housed in an aluminum case with removable front and rear covers, each of which is held in place by six snap catches. The case is equipped with a rigid carrying handle attached to the top. The entire unit is finished in olive drab lusterless enamel.

OPERATION

To operate the gas alarm it must be placed on level ground or a level platform during operation, standing on supporting channels welded to the bottom of the case. If the alarm is not level, the gravity feed of chemical solution to the liquid pump will be affected. After the alarm is leveled remove the cap on the power input connector and insert the plug of the power cable. Refer to figure 11-16 for following procedures:

1. Screw the threaded shell of the cable plug down on the power connector bushing to hold the plug firmly in place.
2. Connect the battery clips on the end of the power cable to the power source. The power source may be either storage batteries (4, each 6 volts or 2, each 12 volts), a generator, or a transformer-rectifier. (The transformer-rectifier, figure 11-17, is a portable power supply unit for the M6A1 Automatic Field Alarm designed to provide 25 volts (direct current) from any 115-volt, 60 cycle alternating current source. The transformer-rectifier is equipped with two power cables, one is to be used to connect the alternating power source to the rectifier, the other connects the rectifier to the gas alarm.) OBSERVE THE POLARITY INDICATED ON THE CLIPS. Failure to observe this precaution will result in stripping the gears of the timing motor.
3. Note the arrows on the cam knob. If the cam knob rotation is not in the direction indicated (counterclockwise), the clips must be reversed.
4. A transformer-rectifier unit may be supplied with the alarm. If so, the power cable

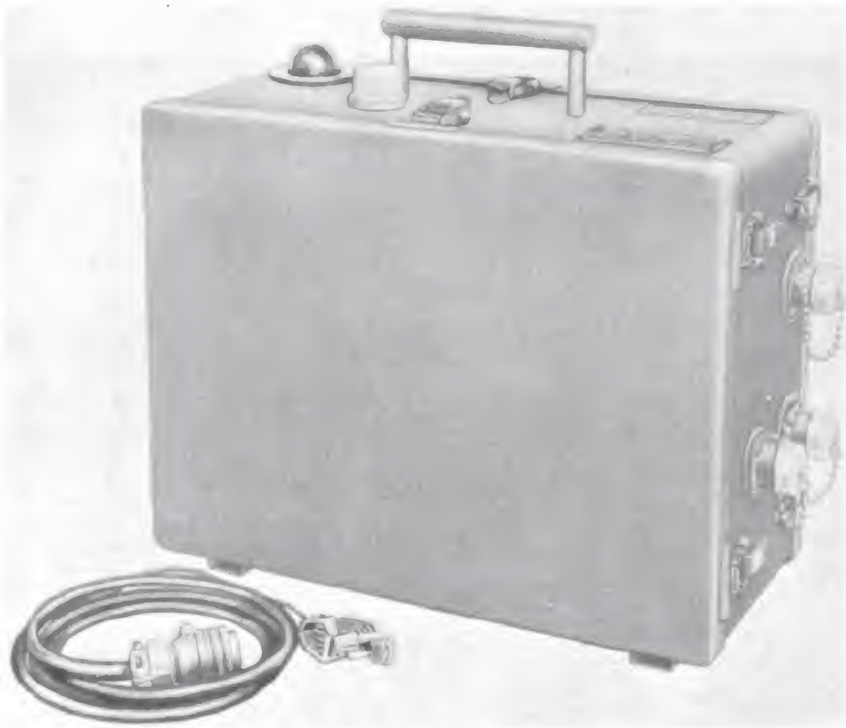

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Figure 11-15.—Automatic field gas alarm M6A1.

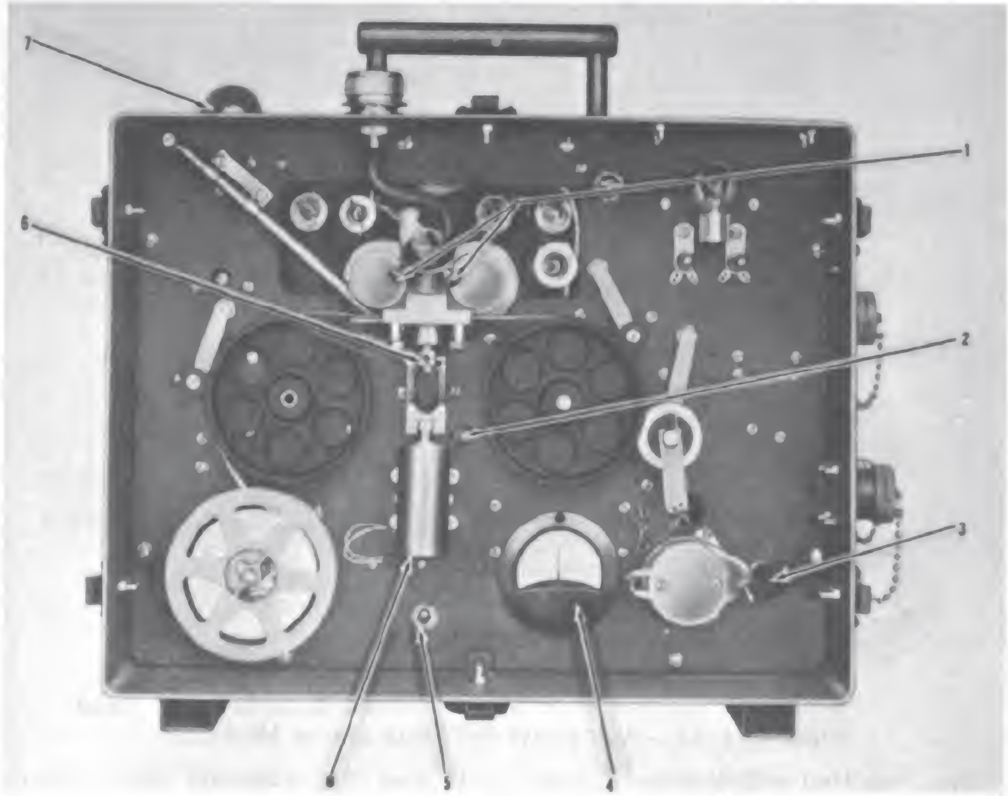
with battery clips, supplied with the alarm will not be used.

5. Shortly after the field alarm is connected to its power source, and while the tubes are warming up, the bridge circuit of the alarm may momentarily become unbalanced, causing an alarm to be given. This condition occurs when the meter indicator moves beyond the second division line to the left of "0." To stop the alarm, simply push the reset switch down and observe the meter. If after a few seconds the meter indicator has not returned to "0" adjust the light source holder by rotating it until the meter indicator reads "0." This adjustment should be made only when dry paper tape is being observed by the phototubes. To test the operation of the alarm, a simulant spot is provided with the reagent kit (fig. 11-18). The simulant spot is used by inserting it over the paper tape into the slot of the head assembly while manually pushing the solenoid fork down. The insertion of the simulant spot must always be made from the left-hand side resulting first in a meter deflection to the right, and then to the left. When pushed in as far as it will go, the alarm should sound. To stop the alarm, withdraw the simulant spot and momentarily push the reset switch down.

Once the gas alarm is set up and ready to operate it goes through the following cycle: At 5 minute intervals, when no G-agents are present in the air, a small quantity of liquid flows from the feeder extension tube onto the section of tape immediately to the left of the head assembly. Approximately 10 to 15 seconds later, the solenoid below the head assembly operates and draws the platen downward, and about 1 second later, the wet section of the tape advances to position in the head assembly. The solenoid is then released and the instrument resumes operation. When the instrument detects G-agents, the meter indicates current flow in excess of 0.10 milliampere to the left of the center mark on the scale, the warning lamp lights, and the buzzer sounds. Cam knob rotation and paper movement ceases. The air pump in the rear of the unit also stops.

Once the alarm circuit is energized, the alarm continues even after G-agents are no longer present in the air. The detection circuit must then be reset. This is done as follows:

1. Manually push the plunger of the solenoid down to release pressure from the tape.



1. Light source adjustment screws
2. Wetting time adjustment screw
3. Cam knob
4. Meter M101
5. Reset switch S101
6. Solenoid adjustment collar
7. Warning lamp
8. Solenoid L101

26.148

Figure 11-16.—Gas Alarm Controls and Instruments.

2. Rotate the right hand tape drum clockwise. This will advance the tape quickly. Rotate the cam knob slowly COUNTERCLOCKWISE to wet the new section of the tape.

3. After the tape is in place, push the reset switch down, hold it for about 3 seconds and release it. The alarm will stop and the unit will resume normal operation.

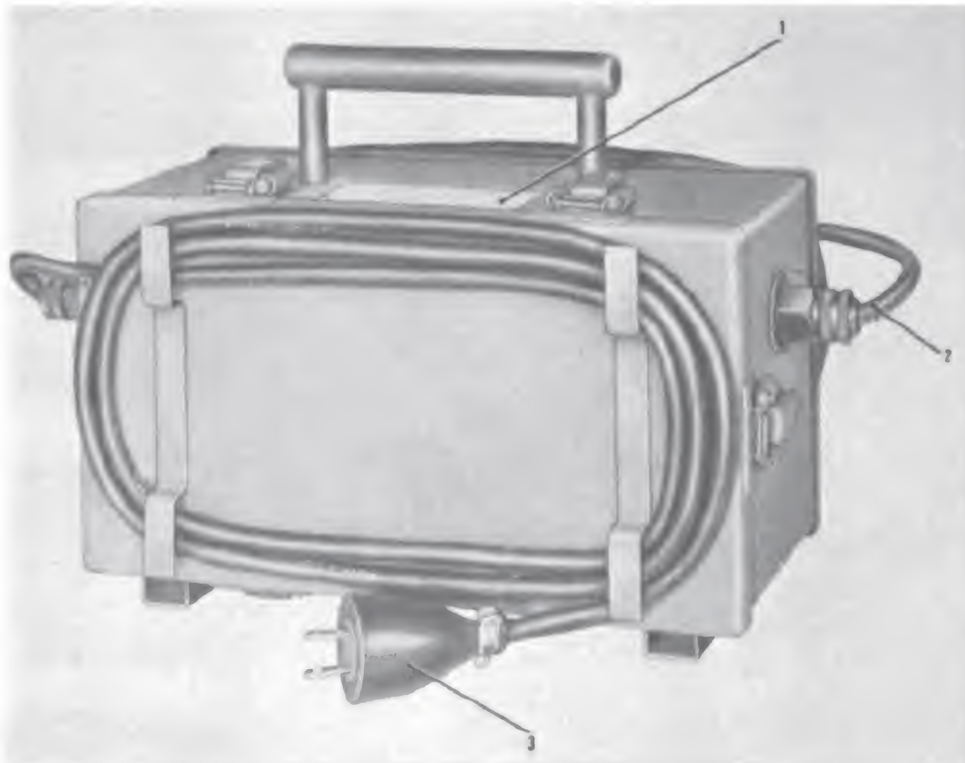
To stop the instrument, disconnect the power cable from the battery, or, if the transformer-rectifier unit is used disconnect the a-c power cable line plug.

MAINTENANCE

In maintaining the M6A1 gas alarm it is imperative that preventive maintenance services be performed regularly to keep the alarm in proper working order and to lessen the possibilities of mechanical failure (Table 11-3).

General maintenance of the M6A1 gas alarm normally involves the replacement of direct-current amplifier and voltage regulator tubes; light source; warning lamps; phototubes; liquid pump; air pump; and timer motor. It also involves cleaning the platen, liquid line, and air pump valves. One other maintenance function you will probably perform is lubrication. Illustrated in figure 11-19 are the various points to be lubricated and the type of lubricant required.

CAUTION: One point you are definitely NOT to lubricate is the air pump valves. Lubrication will cause sticking and fluctuations in the air pressure.



1. Identification Plate
2. Alarm Connecting Cable
3. A. C. Power Cable

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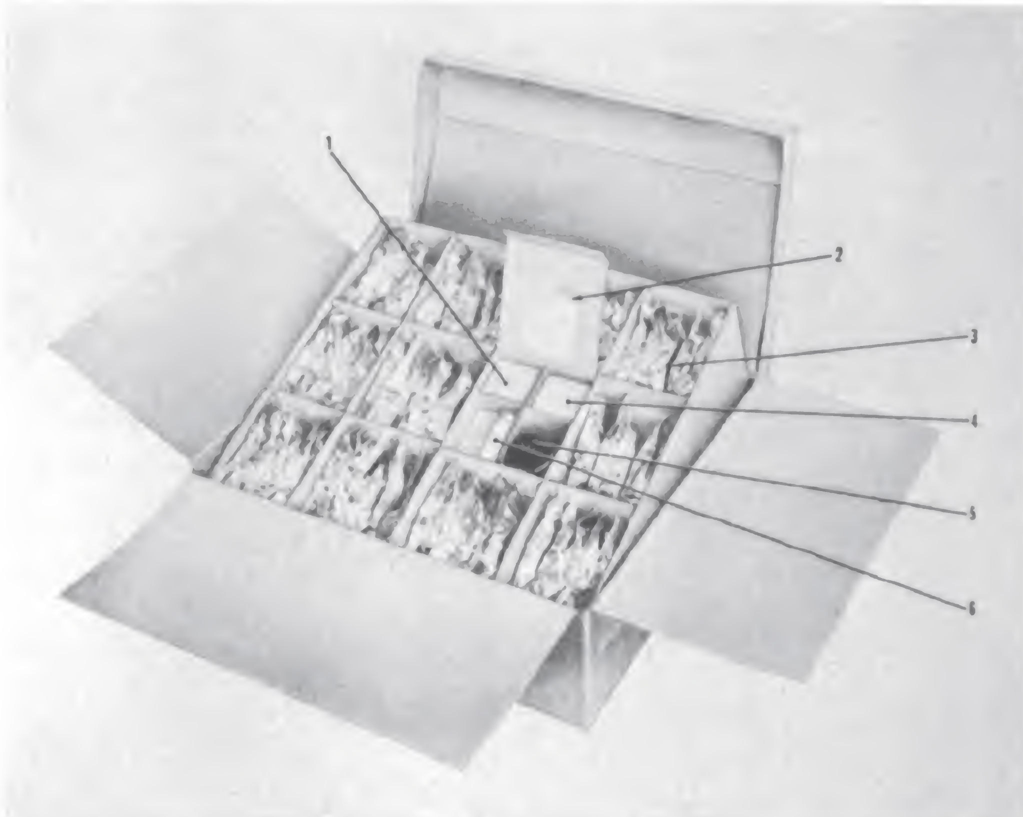
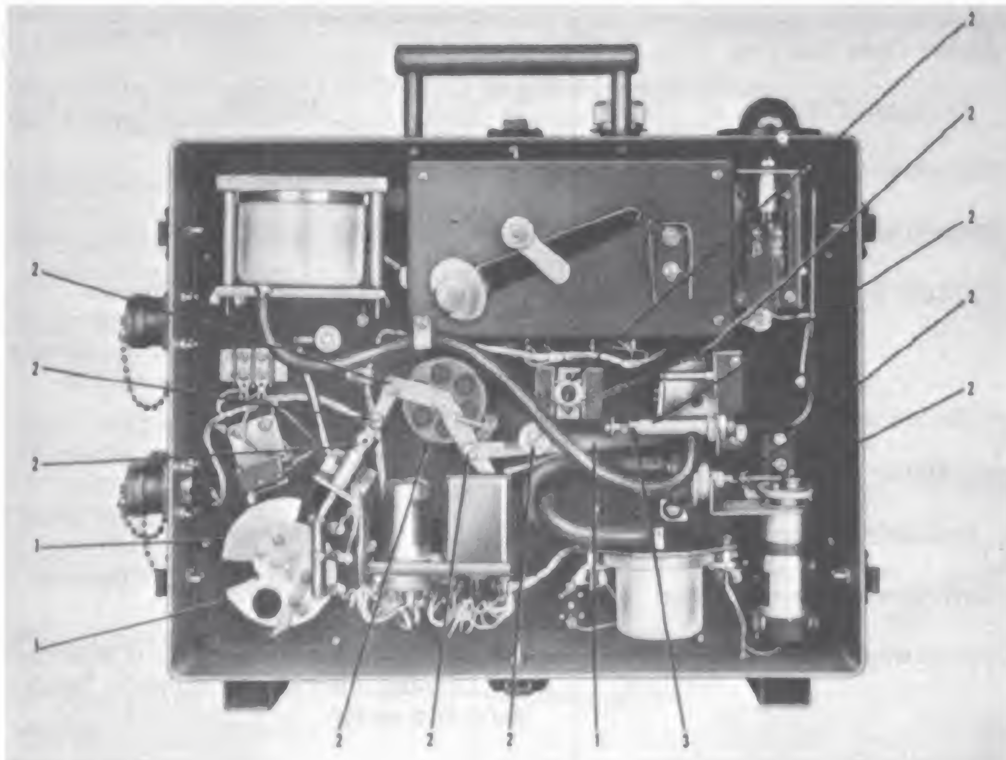
Figure 11-17.—Transformer-Rectifier Unit.



1. Aluminum foil packets
2. Simulant spot
3. Paper reels
4. Clear plastic packets
5. Mixing bottle
6. Filter disks

26.150

Figure 11-18.—Gas-agent alarm, reagent kit.



Point	Lubricant	Spare part kit Item No.
1.	Grease	51
2.	Oil	50
3.	Stop cock grease	52

26.151

Figure 11-19.—Lubrication chart for gas alarm.

Table 11-3.—Troubleshooting Chart for the M6A1 Gas Alarm.

1. Timer Motor Does Not Run	
Probable Cause	Remedy
a. Defective resistor R101	Replace resistor.
b. Defective timing motor	Replace timing motor.
c. Failure of power source	Examine power cables for breaks or deterioration and replace if necessary. Check battery and replace if necessary. If the transformer-rectifier unit is being used.
2. Air Pump Motor Does Not Operate	
Probable Cause	Remedy
a. Defective air pump motor	Replace motor.
b. Pump mechanism jammed	Examine pump mechanism for source of jamming, including bearings. Replace defective parts.
c. Failure of power source	Check power source.
d. Loose shaft	Tighten set screw securing shaft.
3. Liquid Does Not Wet Tape	
Probable Cause	Remedy
a. Liquid tank empty	Refill tank.
b. Air lock in liquid line	Bleed liquid lines.
c. Liquid lines clogged	Dismantle liquid lines, soak in water until clear, and reassemble.
d. Pump spring does not pull piston fully forward	Lubricate piston after cleaning. Replace O-ring if necessary.
4. Tape Does Not Advance	
Probable Cause	Remedy
a. Broken pawl spring	Replace spring.
b. Advance mechanism jammed	Inspect for jammed plunger. Lubricate if required, or replace defective part.
c. Solenoid plunger fails to pull down	Check solenoid and replace if necessary.

Table 11-3.—Troubleshooting Chart for the M6A1 Gas Alarm (Continued)

Probable Cause	Remedy
d. Paper slips on paper advancing reels	Tighten tension roller.
e. Ladder chain too tight	Loosen idler sprocket.
f. Microswitch operating solenoid misadjusted	Readjust microswitch actuator.
g. Plunger return spring too loose	Shorten spring or replace.
h. Tape does not wind properly on bobbin	Adjust tension of spring, holding bobbin against tape drum.
5. Liquid Does Not Flow	
Probable Cause	Remedy
a. Timer motor does not run	See paragraph 1 above.
b. Broken plunger return spring	Replace spring.
6. Timer Motor and Air Pump Motor Do Not Run; Tubes and Lamp Do Not Light	
Probable Cause	Remedy
a. Defective contact on relay K101	Replace relay K101.
b. Failure of power source	Check power source.
7. Tape Breaks During Advancement	
Probable Cause	Remedy
a. Solenoid L101 does not pull plate away from tape due to:	
(1) Improper timing of microswitch S103	Correct timing.
(2) Defective solenoid L101	(a) Check to see that solenoid plunger and platen spring are clean and moving freely; clean if necessary. (b) Replace solenoid.
(3) Defective microswitch S103	Replace switch.
(4) Collar or pull down mechanism adjusted too high	Readjust collar. Travel before plunger hits bottom should not exceed 1/16 inch.

Table 11-3.—Troubleshooting Chart for the M6A1 Gas Alarm (Continued)

Probable Cause	Remedy
b. Ladder chain broken or disengaged from sprocket	Repair chain and replace on sprocket.
c. Too much tension on tape reel	Readjust collar on square shaft to relieve tension.
8. Air Is Not Drawn Through Tape	
Probable Cause	Remedy
a. Air filter clogged	Replace filter disk.
b. Dirt or lint in platen opening	Remove platen, clean and replace.
c. Leak in air line	Inspect air line tubing for cuts. Replace defective section.
d. Defective air pump valve	Remove valves and clean out dust and grit. Replace valve balls if necessary.
e. Loose glass disk below exciter lamp	Recement glass disk in place. Care must be taken to keep glass clean where in line with holes.
f. Leak around phototubes	Remove head and inspect O-rings on phototubes. Apply a light film of stop cock grease to O-rings or replace if found deteriorated. After slipping O-rings over glass part of tube to shoulder, wipe the glass clean before replacing head.
g. Leak in head assembly due to defective O-ring seal or damaged phototube base	Remove the two rubber tubes from the top of the head. Remove the moistener plate. Connect one end of a piece of 3/16 inch ID rubber tubing to the air pump and the other end to one of the inlets from which the air intake tubes were removed. With the air pump operating, place your thumb over the opening, on the bottom of the head, which corresponds with the side to which the air hose is connected. If this side does not leak, a suction on the finger will be noticed and the air pump will labor. Repeat the same test on the other air inlet. If no suction is noticed on one side only, the leak should be found in a defective O-ring seal or a damaged phototube base.

Table 11-3.—Troubleshooting Chart for the M6A1 Gas Alarm (Continued)

Probable Cause	Remedy
9. Detector Circuit Does Not Operate	
Probable Cause	Remedy
a. Burned out or darkened illumination lamp	Replace lamp.
b. Illumination lamp incorrectly positioned	Adjust illumination lamp.
c. Burned out regulator tube V207	Replace tube.
d. Defective relay K102	Replace relay.
e. Defective meter M101	Replace meter.
f. Defective phototube V203, or direct current amplifier tube V201 or V204	Replace each tube in turn to localize trouble.
g. Defective resistor	Perform voltage measurements to localize trouble. Replace any defective components.
10. Alarm Circuit Does Not Operate After Timer Motor Is Replaced	
Probable Cause	Remedy
Timer motor leads reversed	Reverse motor leads.
11. Alarm Operates With No G-Agents Present	
Probable Cause	Remedy
a. Defective phototube V206 or direct current amplifier tubes V202 or V205	Replace tubes V206, V202, and V205 in turn, to localize the trouble.
b. Defective resistor, producing unbalanced circuit condition	Perform voltage measurements to determine location of defective part, and replace the part.

Note: Interference from Other Gases

a. The presence of gases such as chlorine, nitrogen dioxide, cyanogen chloride, and other strong oxidizing agents may discolor the wetted portion of the tape and thus give an alarm.

b. The presence of hydrogen cyanide gas may inhibit the formation of a color spot by G-agent and thus cause the alarm to lose sensitivity or become completely unresponsive.

APPENDIX I

TRAINING FILM LIST

Training films that are directly related to the information presented in this training course are listed below. Under each chapter number and title the training films are identified by Navy number and title and are briefly described. Other training films that may be of interest are listed in the United States Navy Film Catalog, NavPers 10000 (revised).

Chapter 1

THE SCOPE OF YOUR JOB

MN-2088A Discipline—Giving Orders. (15 min.—B&W—Sound—Unclassified—1943.) Stresses importance of discipline and value of giving orders clearly, distinctly, and correctly. Shows results obtained where emphasis is placed on gaining workers confidence and respect, and on where emphasis is placed on making threats and instilling fear in the employees.

MN-3425D Supervision—Building Morale. (15 min.—B&W—Sound—Unclassified—1945.) Visualizes situations which reveal to supervisors techniques which are useful in building and maintaining morale.

ME-5213A Problems in Supervision—The Supervisor as a Leader—Part 1. (14 min.—B&W—Sound—Unclassified—1945.) Several workers point out the qualities found in a good leader.

ME-5213B Problems in Supervision—The Supervisor as a Leader—Part 2. (13 min.—B&W—Sound—Unclassified—1945.) Four Supervisors point out the qualities found in a good leader.

MN-5328B Shipboard Training—Learning by Doing. (13 min.—B&W—Sound—Unclassified—1949.) Illustrates actual shipboard on-the-job training. Emphasizes job analysis and techniques of instruction and training.

ME-5472 Supervising Workers on the Job. (10 min.—B&W—Sound—Unclassified—1944.) Various kinds of poor supervisory practices are shown: nagging, snooping, etc. By dramatized incidents, poor results of these methods are made apparent.

MN-5795G Educational Services—Methods of Teaching. (37 min.—B&W—Sound—Unclassified—1945.) Presents fundamental principles to be observed by educational service officers and instructors in conducting their courses.

Covers preparation of lesson, methods of presentation, class discussions, demonstrations, exploratory quizzes, laboratory work, reviews, and checkups, use of teaching aids, blackboards, slides, recordings, and manuals.

MN-8165 The Importance of Personal Leadership Today. (28 min.—B&W—Sound—Unclassified—1954.) A film report of Admiral Carney's address to the Naval Officers of the Navy Department in Washington, on 11 October 1954 at the Congressional Auditorium. The Chief of Naval Operations outlines his views on the importance of personal leadership in the U.S. Navy. He also states his views on the matter of smartness, discipline and professional competence.

Chapter 2

ELECTRICAL SKETCHING AND PLANNING

SN-34A T-Square and Triangles—Part 1. (32 frames—B&W—Silent—Unclassified—1941.) Describes use of T-Square, 45 and 30-60 degree triangles, and drafting ruler in laying out horizontal and vertical lines on an operations sheet.

SN-34-B T-Square and Triangle—Part 2. (53 frames—B&W—Silent—Unclassified—1941.) Demonstrates use of T-square, triangles, and rulers in drawing six figures involving vertical, horizontal, and angular lines.

SN-35A Geometric Construction—Part 1. (40 frames—B&W—Silent—Unclassified—1941.) Gives information on use and care of compass, dividers, drawing pencil, rule triangles, and protractor. Demonstrates construction of perpendicular bisector, perpendicular at end of a line, parallel lines, dropping a perpendicular, and bisecting an angle.

SN-35B Geometric Construction—Part 2. (35 frames—B&W—Silent—Unclassified—1941.) Demonstrates laying out a fillet, duplicating an angle with a compass, and laying out angles with a protractor.

MN-37 Behind the Shop Drawing. (16 min.—B&W—Sound—Unclassified—1941.) Emphasizes importance of drawings for industrial production. Describes isometric, perspective, orthographic projection, and cross sectional drawings. Shows how dimensions and specifications are indicated on work sheets.

Chapter 3

CONTROLLERS AND PROTECTIVE DEVICES

SN-1449-B Electrical Controls—Part 2. (35 frames—B&W—Silent—Unclassified—1942.) Explains, by use of drawings and schematic diagrams, duties, composition, and operating

principle of the toggle switch, push-button switch, micro switch and wafer switch. Where these types of switches are most commonly found is also discussed.

SN-1449-C Electrical Controls—Part 3. (29 frames—B&W—Silent—Unclassified—1942.) Explains duty of a relay; shows, by means of diagrams, its operating principle; discusses, briefly, fuses and their duties; and explains operating of the thermal overload circuit breaker.

MN-3485-F Electric Power Afloat—Operating AC and DC Motors and Controllers. (16 min.—B&W—Sound—Unclassified—1945.) Animation and diagrams present operating principles of AC and DC motors and controllers. Shows how to perform daily, operational, and periodic checks of the mechanisms. Demonstrates how to operate and maintain the motors, and explains emergency procedures in the event of operational failure.

MN-5109 Protecting Electric Equipment From High Impact Shock. (13 min.—B&W—Sound—Unclassified—1946.) Illustrates causes of high impact shock and the resulting damage to electrical equipment. Preventive maintenance is suggested in each case and ways of performing the maintenance are shown.

Chapter 4

TESTING EQUIPMENT

SN-2448 Wheatstone Bridge. (59 frames—B&W—Silent—Unclassified—1943.) Compares functions of the Wheatstone bridge with water pipe. Shows how used in locating and calculating distance to a short in wire, use in aircraft temperature controls, and measuring nonelectrical effects.

Chapter 5

POWER GENERATORS

SN-3485-D Electric Power Afloat-Paralleling and Securing. (10 min.—88 frames—B&W—Sound—Unclassified—1945.) Shows how to bring two generators to the same voltage, frequency, and phase, and how to connect them to the same bus to share the load. Adjustment made by electrician's mate on the switchboards are given in detail.

SN-3485-C Electric Power Afloat—Starting and Applying Load. (12 min.—98 frames—B&W—Sound—Unclassified—1945.) Using 2200 ton destroyer as an example, shows general placement of forward and after generators and relates them to their prime movers, the steam turbines. Detail steps in starting generator and in making inspections before starting turbo generator are included in the film.

Chapter 6

POWER DISTRIBUTION SYSTEM

(No applicable training films)

Chapter 7

WIRE COMMUNICATION

MA-8994-A Installation and Operation of Switchboard SB-22/PT. (18 min —B&W—Sound—Unclassified—1959.) This film shows the methods of installing and operating the field-type monocord Telephone Switchboard SB-22/PT designed to provide flexible communications between 12 circuits.

Chapter 8

TRAINING

MN-5328-B Shipboard Training Learning by Doing. (13 min.—B&W—Sound—Unclassified—1949.) Illustrates actual shipboard on-the-job training. Emphasizes job analysis and techniques of instruction and training.

Chapter 9

FOREMANSHIP

(No applicable training films)

Chapter 10

DEFENSIVE COMBAT

MA-5325 Close Order Drill-The Squad Platoon. (29 min.—B&W—Sound—Unclassified—1946.) Starts with a montage of military parade and ceremonies; West Point cadets in review, soldiers marching through the streets of the United States and foreign cities. Fact that precision drill is necessary for the orderly movement of military units is emphasized. Montage ends with a scene of an infantry platoon drilling. Platoon splits up into squads, each of which drills separately. Camera then follows one squad through all basic drill formations, ranging from the commands "Forward March" to "Stack Arms".

Chapter 11

ABC WARFARE DEFENSE EQUIPMENT

MN-8694-A Radiac Equipment-Meeting Local Needs Ashore. (11 min.—B&W—Sound—Unclassified—1958.) This film shows how to establish an allowance of radiac equipment for shore activities and explains the nine categories of radiac equipment, showing how they are used, depending upon the station and station function in passive defense.

MN-8694-B Radiac Equipment-Local Care and Maintenance. (10 min.—B&W—Sound—Unclassified—1959.) This film shows that maintenance of radiac equipment can be accomplished locally; stresses care in handling, proper stowage, and proper checks that can be made locally. It shows briefly what is done at a Radiac Facility to keep radiac equipment in operational readiness condition.

APPENDIX II

QUALIFICATIONS FOR ADVANCEMENT IN RATING

CONSTRUCTION ELECTRICIAN (CE)

QUALS CURRENT THROUGH CHANGE 18

GENERAL RATING (applicable to PO1 and CPO only)

SCOPE

Construction Electricians: Plan, supervise, and perform tasks required to install, operate, service, and overhaul electric generating and distribution systems and wire communication systems; control activities of individuals and crews who string, install, and repair interior, overhead, and underground wires and cables and attach and service units such as transformers, switchboards, motors, and controllers; schedule and evaluate installation and operational routines; and train personnel in installation and repair procedures and techniques.

SERVICE RATINGS (applicable to PO3 and PO2 only)

SCOPES

CONSTRUCTION ELECTRICIAN W (Wiring) . . . . CEW

Installs, services, performs preventive maintenance on, and repairs interior wiring systems and secondary electric distribution circuits; and installs motors, generators, controllers, switchboards, distribution panels, and appliances.

CONSTRUCTION ELECTRICIAN P (Power). . . . . CEP

Installs, operates, services, performs preventive maintenance on, makes repairs to, and overhauls electric generating and distribution systems, overhead and underground.

CONSTRUCTION ELECTRICIAN T (Telephone) . . . . CET

Installs, operates, services, performs preventive maintenance on, makes repairs to, and overhauls wire communication systems, overhead and underground.

CONSTRUCTION ELECTRICIAN S (Shop) . . . . CES

Operates, services, performs preventive maintenance on, repairs, and overhauls electric generating equipment, switchboards, distribution panels, motors, generators, and controllers; and repairs and overhauls electric appliances.

PATH OF ADVANCEMENT TO LIMITED DUTY OFFICER

Construction Electricians advance to Limited Duty Officers, Civil Engineer.

NAVY ENLISTED CLASSIFICATION CODES

See Manual of Navy Enlisted Classifications, NavPers 15105-B.

QUALIFICATIONS FOR ADVANCEMENT IN RATING

1. Qualifications for advancement to a higher rate include the qualifications of the lower rate or rates in addition to those stated for the higher rate.
2. Practical factors will be completed before recommendation for participation in the advancement examination. (Bureau of Naval Personnel Manual, NavPers 15791-A, Articles B-2326 and C-7201.)
3. Knowledge factors and knowledge aspects of practical factors will form the basis for questions in the written advancement examination.

Qualifications for advancement in rating	Applicable Rates				
	CEW	CEP	CET	CES	CE
A. WIRING					
1.0 Practical Factors					
1. Make mechanical and soldered electrical connections and splice wire . . .	3	3	3	3	--
2. Make minor repairs to electrical fixtures	3	3	3	3	--
3. Climb poles	3	3	3	3	--
4. Make minor on-site repairs to electric appliances	3	--	--	3	--
5. Install electric wiring, fixtures, and conduits.	3	--	--	--	--
6. Correct minor faults in wiring systems .	3	--	--	3	--
7. Lay out and install interior electrical circuits including service entrance controls and allied equipment	2	--	--	--	--
8. Analyze faults and make on-site repairs to electrical appliances, equipment, and circuits related to interior wiring systems.	2	--	--	--	--
2.0 Knowledge Factors					
1. Common properties of electrical circuits (resistance, inductance, capacitance) and units of electricity (volts, amperes, ohms) and use of Ohm's law.	3	3	3	3	--

Qualifications for advancement in rating	Applicable Rates				
	CEW	CEP	CET	CES	CE
A. WIRING — Continued					
2.0 Knowledge Factors — Continued					
2. Types of information found in the national electric code applicable to individual service rating	2	2	--	2	--
B. ELECTRICAL GENERATORS AND MOTORS					
1.0 Practical Factors					
1. Operate and service advance-base-type generating equipment	--	3	--	--	--
2. Perform preventive maintenance on electric motors and advanced-base-type generating equipment	--	3	--	--	--
3. Synchronize alternators; stand generator switchboard watches and keep operational logs	--	3	--	--	--
4. Rewind, insulate, and bake armatures and field coils	--	--	--	3	--
5. Make major repairs to and overhaul generating and control equipment of advanced base type, excluding prime movers	--	2	--	2	--
6. Analyze and correct faults in electrical equipment and circuits common to maintenance shops	--	--	--	2	--
7. Make major repairs to electric motors, portable generators, and appliances	--	--	--	2	--
8. Locate, analyze, and repair circuit faults common to:					
a. Electric generating and distribution systems	--	2	--	--	--
b. Electric appliances and equipment	--	--	--	2	--
c. Wire communication systems	--	--	2	--	--
9. Install advanced-base-type generators, switchboards, and distribution panels	--	2	--	--	--
2.0 Knowledge Factors					
1. Principles of electrical theory as applied to:					
a. A.c. and d.c. motors	--	--	--	2	--
b. Generators, transformers, and distribution systems	--	2	--	--	--
c. Wire communication systems	--	--	2	--	--

Qualifications for advancement in rating	Applicable Rates				
	CEW	CEP	CET	CES	CE
B. ELECTRICAL GENERATORS AND MOTORS — Continued					
2.0 Knowledge Factors — Continued					
2. Types, construction, characteristics, and uses of a.c. and d.c. motors, transformers, and generators.	--	2	--	2	--
3. Relationship of generator capacity to distribution system capacity; methods of improving power factor.	--	2	--	--	--
C. ELECTRICAL POWER DISTRIBUTION SYSTEMS					
1.0 Practical Factors					
1. Work as crew member erecting pole lines and accessories and installing underground cable for electric distribution systems	--	3	--	--	--
2. Make minor repairs to correct circuit faults in electric distribution systems and equipment.	--	3	--	--	--
3. Analyze and correct faults in electric distribution systems	--	2	--	--	--
4. Install transformers	--	2	--	--	--
5. String overhead electric distribution lines; and install underground power cable.	--	2	--	--	--
6. Install instrument transformers in power distribution circuit.	--	2	--	--	--
7. Splice cable and make connections in electric distribution systems.	--	2	--	--	--
8. Install, troubleshoot, and service all types of automatic controllers	--	--	--	--	1
2.0 Knowledge Factors					
1. Types, uses, and principles of operation of secondary electric circuit protective devices and switches	3	3	3	3	--
2. Primary electric circuit protective devices and switches; controllers, relays, and solenoids	2	3	2	2	--
3. Methods and procedures for making major repairs and overhauling electric relays, solenoids, switches, circuit protective devices, and controllers. . .	--	2	--	2	--

Qualifications for advancement in rating	Applicable Rates				
	CEW	CEP	CET	CES	CE
D. COMMUNICATION SYSTEMS					
1.0 Practical Factors					
1. Work as crew member erecting pole lines and accessories and installing underground telephone cable	--	--	3	--	--
2. Service and charge storage batteries used in wire communication systems .	--	--	3	--	--
3. Make minor repairs to telephone wiring, subsets, and signal circuits.	--	--	3	--	--
4. Install storage and dry cell batteries used for wire communication systems.	--	--	3	--	--
5. Operate and service manual telephone switchboards	--	--	3	--	--
6. Install interior telephone wiring, subsets, signal circuits, public address systems, and interoffice communication systems.	--	--	2	--	--
7. Analyze, correct faults, and make major repairs to signal, telephone, public address, and interoffice communication systems.	--	--	2	--	--
8. String overhead telephone lines and install underground telephone cable. . . .	--	--	2	--	--
9. Splice overhead and underground cable; splice-in telephone cable terminals . .	--	--	2	--	--
10. Repair manual telephone switchboards .	--	--	2	--	--
2.0 Knowledge Factors					
1. Types of manual and automatic telephone equipment used at advanced bases	--	--	3	--	--
E. TOOLS					
1.0 Practical Factors					
1. Select and use common electrical hand and power tools.	3	3	3	3	--
2. Use voltmeter, ammeter, and ohmmeter in testing circuits and equipment .	3	3	3	3	--
3. Operate lathes to turn down commutators	--	--	--	3	--

Qualifications for advancement in rating	Applicable Rates				
	CEW	CEP	CET	CES	CE
D. COMMUNICATION SYSTEMS — Continued					
2.0 Knowledge Factors					
1. Nomenclature and use of tools, materials, and equipment related to:					
a. Electric motors and generators. . .	--	--	--	3	--
b. Electric distribution systems	--	3	--	--	--
c. Wire communication systems	3	--	--	--	--
d. Interior and exterior wiring systems	3	--	--	--	--
2. Types and functions of measuring and testing equipment and devices used in electrical maintenance as applied to individual service ratings.	2	2	2	2	--
3. Principle of operation of Wheatstone bridge, cable fault finders, and power circuit analyzers.	--	--	--	--	1
F. DRAWINGS AND SKETCHES					
1.0 Practical Factors					
1. Read and prepare elementary wiring diagrams to perform tasks on:					
a. Interior wiring systems.	3	--	--	--	--
b. Electric equipment and appliances.	--	--	--	3	--
c. Electric distribution systems	--	3	--	--	--
d. Wire communication systems	--	--	3	--	--
2. Use electrical plans, diagrams, and schematics to install or repair:					
a. Interior wiring.	2	--	--	--	--
b. Electric equipment and appliances.	--	--	--	2	--
c. Electric distribution systems	--	2	--	--	--
d. Wire communication systems	--	--	2	--	--
3. Prepare sketches, employing conventional electrical symbols	--	--	--	--	1
2.0 Knowledge Factors					
1. Electrical symbols used on wiring diagrams and schematics	3	3	3	3	--
G. SAFETY					
1.0 Practical Factors					
1. Perform the following (under simulated conditions):					
a. Rescue of a person in contact with an energized circuit	3	3	3	3	--

Qualifications for advancement in rating	Applicable Rates				
	CEW	CEP	CET	CES	CE
G. SAFETY — Continued					
1.0 Practical Factors — Continued					
b. Resuscitation of a person unconscious from electric shock	3	3	3	3	--
c. First aid treatment for electric shock and burns and chemical burns	3	3	3	3	--
d. Pole-top resuscitation	3	3	3	3	--
2.0 Knowledge Factors					
1. Safety precautions to be observed when working with or in the vicinity of electric circuits and equipment	3	3	3	3	--
2. Safety precautions to be observed when:					
a. Handling molten lead, compound and taping oil used in splicing.	--	3	3	3	--
b. Climbing poles, buildings, and towers to string or work with wires and cables	3	3	3	3	--
c. Charging batteries.	3	3	3	3	--
H. FOREMANSHIP					
1.0 Practical Factors					
1. Prepare inspection and progress reports, job orders, and material requisitions; stow and account for spare parts.	--	--	--	--	1
2. Make equipment and material estimates from drawings, sketches, and specifications	--	--	--	--	1
3. Supervise watch in control room of an electric generating station	--	--	--	--	1
4. Supervise and train personnel engaged the installation, operation, maintenance, and repair of electric generating and distribution systems, interior wiring and wire communications systems, and shop repair of equipment.	--	--	--	--	1
5. Develop operational procedures and prepare reports for electric equipment and systems	--	--	--	--	C
6. Instruct personnel in practical application of a.c. and d.c. theory	--	--	--	--	C

Qualifications for advancement in rating	Applicable Rates				
	CEW	CEP	CET	CES	CE
H. FOREMANSHIP — Continued					
1.0 Practical Factors — Continued					
7. Conduct training programs to qualify personnel for advancement in rating, including cross-training of service rating personnel for advancement to the general rating	--	--	--	--	C
8. Control site deployment of materials and equipment.	--	--	--	--	C
9. Train individuals and drill crews in safe and expeditious execution of assigned tasks	--	--	--	--	C
10. Direct and coordinate composition and efforts of crews	--	--	--	--	C
11. Direct general job operations involving electric generating and distribution systems and wire communication systems.	--	--	--	--	C
2.0 Knowledge Factors					
1. Principles and techniques of supervision and job control.	--	--	--	--	1
I. DEFENSIVE TACTICS					
1.0 Practical Factors					
1. Maneuver fire teams into various formations by the use of hand and arm signals	--	--	--	--	C
2.0 Knowledge Factors					
1. Employment of fire teams in defensive positions	--	--	--	--	C
2. Instructions to be given perimeter guards.	--	--	--	--	C
J. ATOMIC, BIOLOGICAL, AND CHEMICAL (ABC) WARFARE DEFENSE					
1.0 Practical Factors					
1. Perform routine maintenance of radiac gear and gas alarms	--	--	--	--	1
2.0 Knowledge Factors					
None.					

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